# General Standard (Benthic)

# Total Maximum Daily Load Development
# for
# Stock Creek

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# ACKNOWLEDGEMENTS

Virginia Department of Environmental Quality (VADEQ), Central Office

VADEQ, Southwest Regional Office

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Virginia Department of Forestry, Abingdon Regional Office (VADOF)

# EXECUTIVE SUMMARY

## *Background and Applicable Standards*

Stock Creek (waterbody ID # VAS-P13R) was initially listed on the *1998 303(d) Total Maximum Daily Load Priority List and Report* as partially supporting for aquatic life use (VADEQ, 1998). A biological monitoring station located at stream mile 4.73 indicated that the segment was moderately impaired and probably received leachate or runoff from the Cyprus Foote Mineral Company mine tailings. The stream is also groundwater-influenced due to the limestone geology and the prevalence of sinkholes in the area.

Stock Creek remained on Virginia's 2002 303(d) Report on Impaired Waters and the 2004 305(b)/303(d) Water Quality Assessment Integrated Report for violations of the General Standard (benthic). Two biological monitoring stations – 6BSTO0004.73 and 6BSTO005.26 – are moderately impaired.

The General Standard is implemented by the Virginia Department of Environmental Quality (VADEQ) through application of the modified Rapid Bioassessment Protocol II (RBPII). Using the modified RBPII, the health of the benthic macro-invertebrate community is typically assessed through measurement of eight biometrics. Each biometric measured at a target station is compared to the same biometric measured at a reference (non-impaired) station to determine each biometric score. These scores are then summed and used to determine the overall bioassessment (e.g., non-impaired, slightly impaired, moderately impaired, or severely impaired). Using this methodology, Stock Creek was rated as moderately impaired.

## *TMDL Endpoint and Water Quality Assessment*

A Total Maximum Daily Load (TMDL) must be developed for a specific pollutant(s). Benthic assessments are very good at determining if a particular stream segment is impaired or not, but generally do not provide enough information to determine the cause(s) of the impairment. The process outlined in the Stressor Identification Guidance Document (USEPA, 2000) was used to identify stressors affecting Stock Creek. Chemical and physical monitoring data from VADEQ monitoring stations provided evidence to support or eliminate

potential stressors. The potential stressors are: sediment, toxics, low dissolved oxygen, nutrients, pH, metals, conductivity/total dissolved solids, temperature, and organic matter.

The results of the stressor analysis for Stock Creek are divided into three categories:

> **Non-Stressor(s)**: Those stressors with data indicating normal conditions, without water quality standard violations, or without the observable impacts usually associated with a specific stressor, were eliminated as possible stressors.

> **Possible Stressor(s)**: Those stressors with data indicating possible links, but inconclusive data, were considered to be possible stressors.

> **Most Probable Stressor(s)**: The stressor(s) with the most consistent information linking it with the poorer benthic and habitat metrics was considered to be the most probable stressor(s).

The results indicate that sediment is the Most Probable Stressor for Stock Creek and was used to develop the benthic TMDL.

Sediment is delivered to Stock Creek through surface runoff, streambank erosion, and natural erosive processes. During runoff events, sediment is transported to streams from land areas. Rainfall energy, soil cover, soil characteristics, topography, and land management affect the magnitude of sediment loading. Land disturbances from mining, forest harvesting, and construction accelerate erosion at varying degrees.

Sediment transport is a natural and continual process that is often accelerated by human activity. An increase in impervious land without appropriate stormwater control increases runoff volume and peaks, which leads to greater potential for channel erosion. During dry periods, sediment from air or traffic builds up on impervious areas and is transported to streams during runoff events. Fine sediments are included in total suspended solids (TSS) loads that are permitted for wastewater, industrial stormwater, and construction stormwater discharge.

### *Modeling Procedures*

There are no existing in-stream criteria for sediment in Virginia; therefore, a reference watershed approach was used to define allowable TMDL loading rates in the Stock Creek watershed. The Stony Creek watershed was selected as the TMDL reference for Stock Creek

due to the similarity of the watershed characteristics. The TMDL sediment loads were defined as the modeled sediment load for existing conditions from the non-impaired Stony Creek watershed, area-adjusted to the Stock Creek watershed. The Generalized Watershed Loading Function (GWLF) model (Haith et al., 1992) was used for comparative modeling between both the impaired creek and Stony Creek. Only the portion of the watershed upstream of the impaired segment was considered in the modeling and subsequent allocations. The impairment ends at VADEQ monitoring station 6BSTO004.73 approximately one mile downstream from the Bishop Creek confluence.

## Existing Conditions

The sediment TMDL for Stock Creek was defined by the average annual sediment load in metric tons per year (Mg/yr) from the area-adjusted Stony Creek. The sediment loads for existing conditions were calculated using the period of April 1997 through March 2001.

The sediment TMDLs are composed of three components: waste load allocations (WLA) from point sources, the load allocation (LA) from nonpoint sources, and a margin of safety (MOS), which was set to 10% for this study. The target sediment load (from area-adjusted Stony Creek) for Stock Creek was 2,379.22 Mg/yr. The existing load from Stock Creek was 4165.67 Mg/yr. Table ES.1 summarizes the TMDL targets for Stock Creek watershed.

**Table ES.1     TMDL Targets for Stock Creek Watershed.**

| Impairment | WLA (Mg/yr) | LA (Mg/yr) | MOS | TMDL (Mg/yr) |
|---|---|---|---|---|
| Stock Creek | 0.00 | 2,379.23 | 264.36 | 2,643.58 |

## Load Allocation Scenarios

The next step in the sediment TMDL process was to reduce the various source loads to result in average annual sediment loads less than the target sediment TMDL load. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality. Allocations were developed at the outlet of Stock Creek.

The final load allocation scenario for Stock Creek required a 42.88% reduction in sediment. The sediment reduction will target loads from all barren areas, disturbed forest, agriculture,

quarries, stream bank erosion and abandoned mine land. No reductions to permitted sources were required.

### Implementation

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the benthic impairment on Stock Creek. The second step is to develop a TMDL implementation plan (IP). The final step is to implement the TMDL IP and to monitor stream water quality to determine if water quality standards are being attained.

While section 303(d) of the Clean Water Act (CWA) and current United States Environmental Protection Agency (EPA) regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Once a TMDL IP is developed, VADEQ will take the plan to the State Water Control Board (SWCB) for approval for implementing the pollutant allocations and reductions contained in the TMDL. Also, VADEQ will request SWCB authorization to incorporate the TMDL implementation plan into the appropriate waterbody. With successful completion of implementation plans, Virginia will be well on the way to restoring impaired waters and enhancing the value of this important resource.

It is anticipated that disturbed forest will be the initial target of implementation. Erosion and sediment deposition from disturbed forest areas generally abate over time as new growth emerges. One practice that has been successful on some sites involves diversion ditches to direct water away from the disturbed area. Because logging is a common practice in the watershed, every effort must be made to ensure that the proper forest harvesting BMPs are used on future harvests.

There is a measure of uncertainty associated with the final allocation development process. Monitoring performed upon completion of specific implementation milestones can provide insight into the effectiveness of implementation strategies, the need for amending the plan, and/or progress toward the eventual removal of the impairment from the 303(d) list.

### Public Participation

During development of the TMDL for Stock Creek, public involvement was encouraged through two public meetings. An introduction of the agencies involved, an overview of the TMDL process, and the specific approach to developing the Stock Creek TMDL were presented at the first of the public meetings. Details of the pollutant sources and stressor identification were also presented at this meeting. Public understanding of, and involvement in, the TMDL process was encouraged. Input from this meeting was utilized in the development of the TMDL and improved confidence in the allocation scenarios. The final model simulations and the TMDL load allocations were presented during the final public meeting. There was a 30-day public comment period after the final public meeting and no written comments were received. Watershed stakeholders will have the opportunity to participate in the development of the TMDL IP.

# 1.  INTRODUCTION

## 1.1   Background

The need for a Total Maximum Daily Load (TMDL) for the Stock Creek watershed was based on provisions of the Clean Water Act.  The United States Environmental Protection Agency's (EPA) document, *Guidance for Water Quality-Based Decisions: The TMDL Process* (EPA, 1999), states:

> *According to Section 303(d) of the Clean Water Act and the USEPA water quality planning and management regulations, States are required to identify waters that do not meet or are not expected to meet water quality standards even after technology-based or other required controls are in place. The waterbodies are considered water quality-limited and require TMDLs.*
>
> *…A TMDL is a tool for implementing State water quality standards, and is based on the relationship between pollution sources and in-stream water quality conditions. The TMDL establishes the allowable loadings or other quantifiable parameters for a waterbody and thereby provides the basis for States to establish water quality-based controls. These controls should provide the pollution reduction necessary for a waterbody to meet water quality standards.*

The Stock Creek watershed (within USGS Hydrologic Unit Code #06010205) is located in Scott County, Virginia (Figure 1.1).  Stock Creek flows through Mabe and near Sunbright along routes 653 and 871, to the east of Duffield in Scott County.  The impaired segment is between Sunbright and Natural Tunnel State Park off of Route 871.  The 0.69 mile segment begins downstream of the impoundment near what was once the Cyprus Foote Mineral Company and, subsequently, the Chemetall Foote Corporation Sunbright facility.  Stock Creek is part of the Tennessee/Big Sandy River Drainage Basin, and drains via the Mississippi River to the Gulf of Mexico.  The land area of the Stock Creek watershed is approximately 11,081 acres.

Stock Creek (waterbody ID # VAS-P13R) was initially listed on the *1998 303(d) Total Maximum Daily Load Priority List and Report* as partially supporting for aquatic life use (VADEQ, 1998).   A biological monitoring station located at stream mile 4.73 indicated that the segment was moderately impaired and probably received leachate or runoff from the

Cyprus Foote Mineral Company mine tailings. The stream is also groundwater-influenced due to the limestone geology and the prevalence of sinkholes in the area.

Stock Creek remained on Virginia's *2002 303(d) Report on Impaired Waters* and the *2004 305(b)/303(d) Water Quality Assessment Integrated Report* for violations of the General Standard (benthic). Two biological monitoring stations – 6BSTO0004.73 and 6BSTO005.26 – are moderately impaired in the reach. In the 2004 report, the Aquatic Life Use designation was changed to 'Not Supporting'.
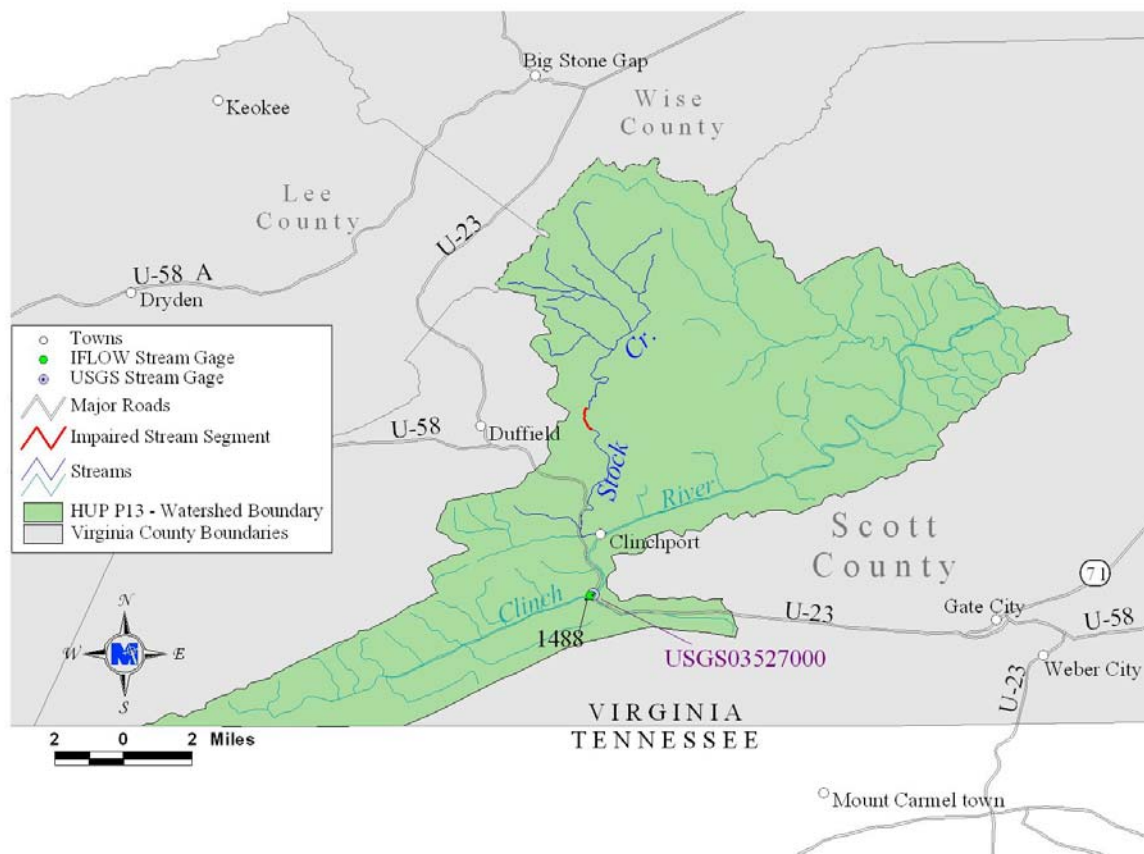


**Figure 1.1** **Location of the Stock Creek watershed.**

## 2. WATER QUALITY ASSESSMENT

### 2.1 Applicable Water Quality Standards

Virginia state law 9VAC25-260-10 (Designation of uses) indicates:

A. *All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of <u>a balanced, indigenous population of aquatic life</u>, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish.*

♦

D. *At a minimum, uses are deemed attainable if they can be achieved by the imposition of effluent limits required under §§301(b) and 306 of the Clean Water Act and cost-effective and reasonable best management practices for nonpoint source control.*

♦

G. *The [State Water Control] board may remove a designated use which is not an existing use, or establish subcategories of a use, if the board can demonstrate that attaining the designated use is not feasible because:*
   1. *Naturally occurring pollutant concentrations prevent the attainment of the use;*
   2. *Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation requirements to enable uses to be met;*

♦

   6. *Controls more stringent than those required by §§301(b) and 306 of the Clean Water Act would result in substantial and widespread economic and social impact.*

### 2.2 Applicable Criterion for Benthic Impairment

Additionally, Virginia state law 9VAC25-260-20 defines the **<u>General Standard</u>** as:

*A. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or <u>aquatic life</u>.*

### 2.3 Benthic Assessment

Stock Creek was initially listed on the *1998 303(d) Total Maximum Daily Load Priority List and Report* as being partially supporting for aquatic life use due to moderately impaired

ratings at Virginia Department of Environmental Quality (VADEQ) benthic monitoring station 6BSTO004.73 (Figure 2.1).  Stock Creek remained on the *2002 Section 303(d) Report on Impaired Waters* and the *2004 Section 303(d) Water Quality Assessment Integrated Report*.
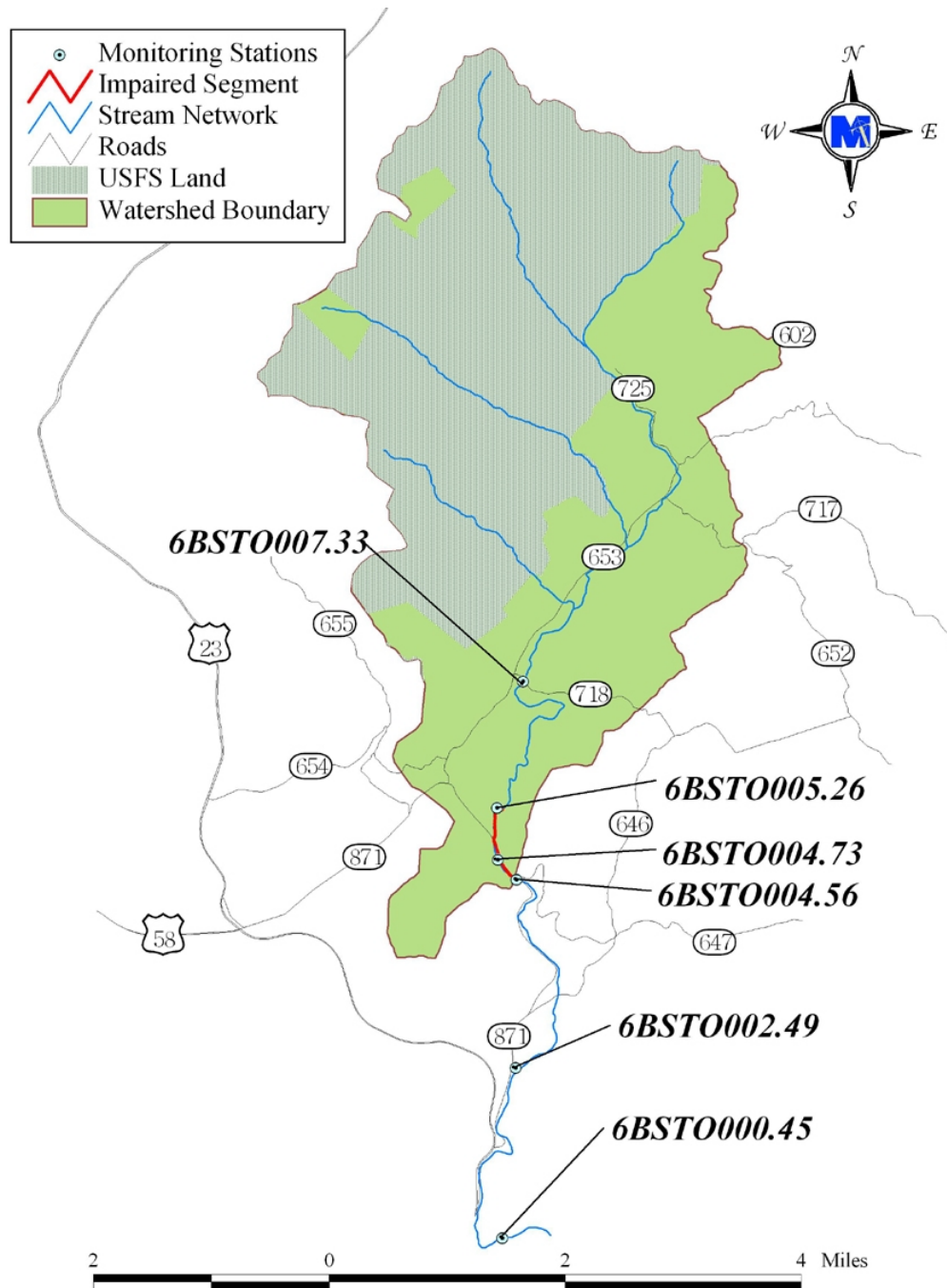


**Figure 2.1     Location of VADEQ in-stream water quality monitoring stations on Stock Creek.**

The General Standard is implemented by VADEQ through application of the modified Rapid Bioassessment Protocol II (RBP II).  Using the modified RBP II, the health of the benthic macroinvertebrate community is typically assessed through measurement of eight biometrics (Table 2.1) which measure different aspects of the community's overall health.  Surveys of the benthic macroinvertebrate community performed by VADEQ are assessed at the family taxonomic level.

**Table 2.1        Components of the RBP II Assessment.**

| Biometric | Benthic Health [1] |
|---|:---:|
| Taxa Richness | ↑ |
| Modified Family Biotic Index | ↓ |
| Scraper to Filtering Collector Ratio | ↑ |
| EPT / Chironomid Ratio | ↑ |
| % Contribution of Dominant Family | ↓ |
| EPT Index | ↑ |
| Community Loss Index | ↓ |
| Shredder to Total Ratio | ↑ |

[1] An upward arrow indicates a positive response in benthic health when the associated biometric increases.

Each biometric measured at a target station is compared to the same biometric measured at a reference (non-impaired) station to determine each biometric score.  These scores are then summed and used to determine the overall bioassessment (*e.g.,* not impaired, slightly impaired, moderately impaired, or severely impaired).

RBP II benthic surveys were performed by the VADEQ in fall 1992, fall 1993, spring and fall 1995, spring and fall 1997, spring 1998, fall 2003, and spring 2004 (spring 2005 sampling has been completed but RBP II results haven't been calculated).  Tables 2.2 through 2.4 show the results of the benthic monitoring on Stock Creek, the reference station used for comparison is also shown in the tables.  Table 2.2 shows that VADEQ station 6BSTO004.73 was severely impaired in fall 1995.  Tables 2.2 and 2.3 show that stations 6BSTO004.73 and 6BSTO005.26 were moderately impaired in fall 1997.  Results shown for benthic monitoring station 6BSTO000.45 (Table 2.4) are for informational purposes only.  This station is not located within the impaired segment.

**Table 2.2      RBP II benthic assessments for station 6BSTO004.73 on Stock Creek.**

| Date | Assessment | Reference Station |
|------|-----------|-------------------|
| Fall 1992 | Slight Impairment | 6CNFH098.47 |
| Fall 1993 | Slight Impairment | 6CNFH080.45 |
| Spring 1995 | Moderate Impairment | 6BSTO005.26 |
| Fall 1995 | Severe Impairment | 6BSTO005.26 |
| Spring 1997 | Moderate Impairment | 6BSTO005.26 |
| Fall 1997 | Moderate Impairment | 9-RDC033.83 |
| Spring 1998 | Not Impaired | 6BWAL001.57 |
| Fall 1998 | Not Impaired | 6CNFH098.47 |
| Fall 2003 | Not Impaired | 6CMFH045.31 |
| Spring 2004 | Not Impaired | 6CSFH098.47 |

**Table 2.3      RBP II benthic assessments for station 6BSTO005.26 on Stock Creek.**

| Date | Assessment | Reference Station |
|------|-----------|-------------------|
| Fall 1992 | Moderate Impairment | 6CNFH098.47 |
| Fall 1993 | Slight Impaired | 6CNFH080.45 |
| Spring 1995 | Moderate Impairment | 6BSTN000.23 |
| Fall 1995 | Not Impaired | NA[1] |
| Spring 1997 | Moderate Impairment | 6BSTN000.23 |
| Fall 1997 | Moderate Impairment | 9-RDC033.83 |
| Spring 1998 | Not Impairment | 6BWAL001.57 |
| Fall 1998 | Moderate Impairment | 6CNFH098.47 |

[1]6BSTO005.26 was used as the reference station for 6BSTO004.73 in this survey.

**Table 2.4      RBP II benthic assessments for station 6BSTO000.45 on Stock Creek.**

| Date | Assessment | Reference Station |
|------|-----------|-------------------|
| Fall 1992 | Not Impaired | 6CNFH098.47 |
| Fall 1993 | Severe Impairment[*] | 6CNFH080.45 |

[*]Only 65 organisms were found due to recent scouring from flooding and new bridge construction. It should be noted that there was a good diversity of pollution-sensitive organisms.

An alternative method to the modified RBP II is the Virginia Stream Condition Index (VASCI). The VASCI is being developed and data is being collected to calibrate and further validate the VASCI method. Eight biometrics are obtained, with higher scores indicating a healthier benthic community. The advantage of the VASCI is that the score does not depend upon values from a reference station. The VASCI has an impairment threshold of 61.3 and the scores for the VADEQ surveys are presented in Tables 2.5 through 2.7. Station 6BSTO004.73 (Table 2.5) was very close to the impairment threshold in 1992 and 1993 but there was a dramatic decline in index scores in both 1995 surveys. Since 1998 there has been

considerable improvement, and three of the past four surveys indicated no impairment. Station 6BSTO005.26 (Table 2.6) had relatively good scores until fall 1997 when it showed a dramatic decline. The last survey at this station was spring 1998 and the result was well above the impairment threshold value of 61.3. VADEQ station 6BSTO000.45 was monitored in 1992 and the VASCI score was above the impairment threshold (Table 2.7). Station 6BSTO000.45 was monitored again in 1993, but that sample was too small to survey because of scouring due to recent flooding. Figure 2.2 is a graphical representation of the VASCI scores for VADEQ monitoring stations 6BSTO000.45, 6BSTO004.73 and 6BSTO005.26. These VASCI scores show the same pattern as the RBP II scores, *i.e.,* lower values in 1995 and/or 1997 than in other time periods.

**Table 2.5**      **VASCI data for the VADEQ benthic surveys at station 6BSTO004.73 on Stock Creek (Impairment threshold = 61.3).**

| Date | 11/92 | 12/93 | 03/95 | 12/95 | 04/97 | 11/97 | 05/98 | 9/98 | 12/03 | 06/04 | 5/05 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Richness Score | 59.09 | 50.00 | 45.45 | 22.73 | 50.00 | 50.00 | 45.45 | 40.91 | 63.64 | 59.09 | 68.18 |
| EPT Score | 63.64 | 54.55 | 36.36 | 27.27 | 54.55 | 45.45 | 63.64 | 36.36 | 31.76 | 72.73 | 72.73 |
| %Ephem Score | 12.55 | 30.21 | 47.31 | 1.65 | 20.61 | 10.64 | 58.73 | 40.78 | 74.57 | 41.95 | 49.28 |
| %PT-H Score | 83.34 | 100.0 | 16.85 | 22.70 | 20.70 | 9.16 | 100.0 | 11.09 | 17.13 | 45.48 | 35.11 |
| %Scraper Score | 28.36 | 28.38 | 8.06 | 1.63 | 3.40 | 28.05 | 45.16 | 33.96 | 82.3 | 41.47 | 52.08 |
| %Chironomidae Score | 70.33 | 95.37 | 64.00 | 18.18 | 57.89 | 67.39 | 91.00 | 65.79 | 74.07 | 90.48 | 90.63 |
| %2Dom Score | 66.60 | 36.08 | 54.83 | 13.12 | 33.42 | 61.17 | 67.82 | 62.66 | 82.25 | 90.70 | 88.68 |
| %MFBI Score | 87.27 | 100.0 | 72.65 | 65.95 | 68.42 | 74.01 | 100.0 | 75.46 | 50.0 | 87.68 | 83.64 |
| **VASCI** | **58.90** | **61.82** | **43.19** | **21.65** | **38.62** | **43.23** | **71.48** | **45.88** | **59.46** | **66.20** | **67.54** |

**Table 2.6**      **VASCI data for the VADEQ benthic surveys at station 6BSTO005.26 on Stock Creek (Impairment threshold = 61.3).**

| Date | 11/92 | 12/93 | 03/95 | 12/95 | 04/97 | 11/97 | 05/98 |
|---|---|---|---|---|---|---|---|
| Richness Score | 36.36 | 45.45 | 54.55 | 50.00 | 68.18 | 40.91 | 68.18 |
| EPT Score | 36.36 | 45.45 | 45.45 | 63.64 | 63.64 | 36.36 | 81.82 |
| %Ephem Score | 100.00 | 100.00 | 100.00 | 81.57 | 62.29 | 21.75 | 38.68 |
| %PT-H Score | 35.80 | 25.54 | 0.00 | 88.54 | 15.32 | 7.02 | 63.71 |
| %Scraper Score | 26.88 | 62.32 | 29.33 | 19.28 | 17.60 | 6.72 | 44.90 |
| %Chironomidae Score | 98.04 | 97.73 | 95.96 | 86.96 | 66.36 | 71.67 | 76.29 |
| %2Dom Score | 38.20 | 53.57 | 43.73 | 45.49 | 69.53 | 51.71 | 81.82 |
| %MFBI Score | 100.00 | 97.82 | 99.67 | 100.00 | 81.28 | 68.50 | 88.69 |
| **VASCI** | **58.96** | **65.98** | **58.59** | **66.93** | **55.52** | **38.08** | **68.01** |

**Table 2.7    VASCI data for the VADEQ benthic surveys at station 6BSTO000.45 on Stock Creek (Impairment threshold = 61.3).**

| Date | 11/92 |
|---|---|
| Richness Score | 40.91 |
| EPT Score | 54.55 |
| %Ephem Score | 63.44 |
| %PT-H Score | 46.82 |
| %Scraper Score | 44.80 |
| %Chironomidae Score | 98.15 |
| %2Dom Score | 73.49 |
| %MFBI Score | 96.41 |
| **VASCI** | **64.82** |
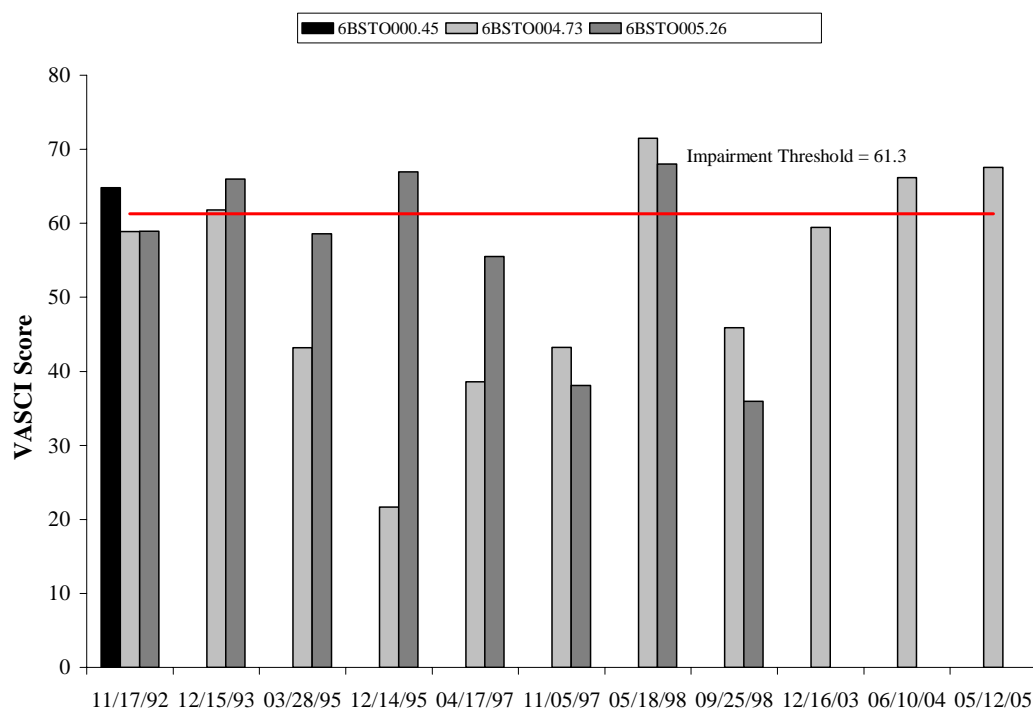


**Figure 2.2    Combined VASCI scores for three VADEQ monitoring stations on Stock Creek.**

## 2.4  Habitat Assessment

Benthic impairments have two general causes: input of pollutants to streams and alteration of habitat in either the stream or the watershed.  Habitat can be altered directly (*e.g.,* by channel

modification), indirectly (because of changes in the riparian corridor leading to conditions such as streambank destabilization), or even more indirectly (*e.g.,* due to land use changes in the watershed such as clearing large areas).

Habitat assessments are normally carried out as part of the benthic sampling. The overall habitat score is the sum of 10 individual metrics, each metric ranging from 0 to 20. The classification schemes for both the individual habitat metrics and the overall habitat score are shown in Table 2.8.

**Table 2.8       Classification of habitat metrics based on score.**

| Habitat Metric | Optimal | Sub-optimal | Marginal | Poor |
|---|---|---|---|---|
| Embeddedness | 16 – 20 | 11 – 15 | 6 – 10 | 0 – 5 |
| Epifaunal Substrate | 16 – 20 | 11 – 15 | 6 – 10 | 0 – 5 |
| Pool Sediment | 16 – 20 | 11 – 15 | 6 – 10 | 0 – 5 |
| Flow | 16 – 20 | 11 – 15 | 6 – 10 | 0 – 5 |
| Channel Alteration | 16 – 20 | 11 – 15 | 6 – 10 | 0 – 5 |
| Riffles | 16 – 20 | 11 – 15 | 6 – 10 | 0 – 5 |
| Velocity | 16 – 20 | 11 – 15 | 6 – 10 | 0 – 5 |
| Bank Stability | 18 – 20 | 12 – 16 | 6 – 10 | 0 – 4 |
| Bank Vegetation | 18 – 20 | 12 – 16 | 6 – 10 | 0 – 4 |
| Riparian Vegetation | 18 – 20 | 12 – 16 | 6 – 10 | 0 – 4 |
| **Overall Score** | 166 – 200 | 113 – 153 | 60 – 100 | 0 – 47 |

Habitat assessment for Stock Creek includes an analysis of habitat scores recorded by the VADEQ biologist. Habitat scores for VADEQ benthic monitoring stations 6BSTO004.73 and 6BSTO005.26 are shown in Tables 2.9 and 2.10. Two metrics had an overall median score of 'marginal' at station 6BSTO004.73. Bank stability is a measure of the erosion potential of the stream bank. Steep banks are, in general, more prone to erosion. A marginal score indicates that 30 – 60% of the bank in the reach area has high erosion potential during flooding. Riparian vegetation is a measure of the natural vegetation from the bank's edge through the riparian zone. A marginal score indicates a zone width of 6 – 12 meters on each bank, and human activity has had a great deal of impact in the riparian zone. Even though the overall embeddedness score was good during the 1995 and 1997 surveys, this metric was in the marginal category. This indicates that substrate in the riffle area was 50 to 75% covered by fine sediment during those surveys. Only one metric (Bank Stability) had an overall marginal score at Station 6BSTO005.26. Average total habitat scores were significantly higher at Station 6BSTO005.26 (160) than at Station 6BSTO004.73 (134).

**Table 2.9    Habitat scores for VADEQ monitoring station 6BSTO004.73 on Stock Creek.**

| Metric | 03/95 | 12/95 | 04/97 | 11/97 | 05/98 | 9/98 | 12/03 | 06/04 | 5/05 |
|--------|-------|-------|-------|-------|-------|------|-------|-------|------|
| Channel Alteration | 15 | 17 | 17 | 19 | 16 | 17 | 18 | 19 | 16 |
| Bank Stability | 8 | 7 | 11 | 17 | 7 | 7 | 10 | 9 | 12 |
| Bank Vegetation | 13 | 16 | 18 | 19 | 17 | 17 | 8 | 15 | 12 |
| Embeddedness | 9 | 11 | 8 | 11 | 11 | 13 | 13 | 16 | 15 |
| Flow | 18 | 19 | 18 | 16 | 18 | 8 | 18 | 19 | 16 |
| Riffles | 14 | 13 | 11 | 13 | 10 | 10 | 12 | 17 | 14 |
| Riparian Vegetation | 6 | 7 | 6 | 19 | 5 | 8 | 6 | 13 | 9 |
| Pool Sediment | 16 | 16 | 18 | 10 | 10 | 7 | 14 | 9 | 15 |
| Epifaunal Substrate | 15 | 15 | 15 | 15 | 14 | 13 | 16 | 19 | 16 |
| Velocity | 9 | 15 | 10 | 10 | 13 | 6 | 15 | 10 | 10 |
| **TOTAL SCORE** | **123** | **136** | **132** | **149** | **121** | **106** | **130** | **146** | **136** |

**Table 2.10    Habitat scores for VADEQ monitoring station 6BSTO005.26 on Stock Creek.**

| Metric | 03/95 | 12/95 | 04/97 | 11/97 | 05/98 | 9/98 |
|--------|-------|-------|-------|-------|-------|------|
| Channel Alteration | 19 | 15 | 15 | 15 | 14 | 13 |
| Bank Stability | 15 | 10 | 9 | 15 | 7 | 11 |
| Bank Vegetation | 18 | 19 | 18 | 19 | 17 | 18 |
| Embeddedness | 16 | 18 | 14 | 18 | 13 | 16 |
| Flow | 18 | 19 | 18 | 14 | 18 | 8 |
| Riffles | 18 | 17 | 18 | 17 | 16 | 16 |
| Riparian Vegetation | 19 | 18 | 18 | 18 | 18 | 18 |
| Pool Sediment | 17 | 18 | 17 | 10 | 16 | 16 |
| Epifaunal Substrate | 18 | 15 | 17 | 15 | 17 | 18 |
| Velocity | 15 | 15 | 15 | 14 | 15 | 17 |
| **TOTAL SCORE** | **173** | **164** | **159** | **155** | **151** | **147** |

## 2.5  Discussion of In-stream Water Quality

This section provides an inventory of available observed in-stream monitoring data throughout the Stock Creek watershed.  Data from water quality stations used in the Section 305(b) assessment and data collected during TMDL development were analyzed.  Sources of data and pertinent results are discussed.

### 2.5.1  Inventory of Water Quality Monitoring Data

The primary source of recent (1990 – 2004) water quality information for Stock Creek is data collected at the three monitoring stations described in Table 2.11.  The data is summarized in Tables 2.12 through 2.16.

**Table 2.11      VADEQ monitoring stations in Stock Creek.**

| Station | Type | Data Record |
| --- | --- | --- |
| 6BSTO004.56 | Ambient | 1/1990 – 6/2004 |
| 6BSTO004.73 | Biological[1] | 3/1995 – 9/1998 |
| 6BSTO005.26 | Ambient/Biological | 8/2003 – 4/2004 |
| 6BSTO007.33 | Ambient | 8/2003 – 4/2004 |

[1]Field parameters are collected at biological monitoring stations.

**Table 2.12    In-stream water quality data at 6BSTO004.56 (1/90-6/04).**

| Water Quality Constituent | Mean | Median | Max | Min | SD[1] | N[2] |
|---|---|---|---|---|---|---|
| Alkalinity, Total, mg/L | 94.0 | 65.9 | 1,289.0 | 28.6 | 157.8 | 62 |
| BOD 5, mg/L | 1.0 | 1.0 | 1.3 | 1.0 | 0.1 | 26 |
| Calcium, Total, mg/L | 18,367 | 16,690 | 25,810 | 12,600 | 6,763 | 3 |
| Chloride, Total, mg/L | 2.3 | 1.5 | 9.0 | 0.3 | 2.0 | 34 |
| COD, High Level, mg/L | 5.8 | 6.1 | 13.0 | 1.0 | 3.2 | 31 |
| Conductivity, μmhos/cm | 152 | 138 | 297 | 62 | 62 | 73 |
| DO, mg/L | 10.5 | 10.6 | 14.7 | 7.0 | 1.5 | 74 |
| Field pH, std units | 7.9 | 7.8 | 9.5 | 6.8 | 0.5 | 74 |
| Fluoride, Total, mg/L | 0.10 | 0.10 | 0.10 | 0.10 | 0.00 | 6 |
| Hardness, calculated, mg/L | 75.3 | 88.4 | 98 | 42.4 | 24.3 | 5 |
| NH3+NH4-N, Total, mg/L | 0.06 | 0.04 | 0.13 | 0.04 | 0.05 | 4 |
| Nitrogen, Total, mg/L | 0.50 | 0.25 | 1.49 | 0.16 | 0.45 | 12 |
| NO2 and NO3 N, Total, mg/L | 0.18 | 0.18 | 0.27 | 0.11 | 0.05 | 12 |
| NO2-N, Total, mg/L | 0.02 | 0.02 | 0.04 | 0.01 | 0.01 | 6 |
| NO3-N, Total, mg/L | 0.21 | 0.19 | 0.45 | 0.05 | 0.08 | 59 |
| Phosphorus, dissolved Ortho, mg/L | 0.02 | 0.01 | 0.04 | 0.01 | 0.01 | 12 |
| Phosphorus, Total, mg/L | 0.02 | 0.02 | 0.10 | 0.01 | 0.03 | 54 |
| Phosphorus, Total Ortho, mg/L | 0.02 | 0.01 | 0.05 | 0.01 | 0.01 | 28 |
| Solids, Organic suspended, mg/L | 1.8 | 1.0 | 5.0 | 0.0 | 1.4 | 19 |
| Solids, Total dissolved, mg/L | 83 | 74 | 172 | 42 | 33 | 30 |
| Solids, Total inorganic suspended, mg/L | 5.6 | 4.0 | 17.0 | 1.0 | 4.4 | 25 |
| Solids, Total inorganic, mg/L | 77.3 | 74.5 | 141.0 | 24.0 | 27.9 | 62 |
| Solids, Total organic, mg/L | 22.7 | 20.0 | 65.0 | 0.0 | 12.8 | 62 |
| Solids, Total suspended, mg/L | 8.1 | 4.0 | 77.0 | 1.0 | 13.0 | 35 |
| Solids, Total, mg/L | 100.1 | 92.5 | 175.0 | 43.0 | 36.0 | 62 |
| Sulfate, Total, mg/L | 9.5 | 8.7 | 25.7 | 6.8 | 3.2 | 60 |
| Temperature, Celsius | 12.8 | 12.7 | 24.1 | 2.2 | 6.0 | 74 |
| Nitrogen, Total Kjeldahl, mg/L | 0.2 | 0.2 | 0.4 | 0.1 | 0.1 | 46 |
| Total Hardness, mg/L | 74.8 | 67.0 | 152.0 | 32.0 | 30.1 | 61 |
| Total Organic Carbon, mg/L | 1.60 | 1.35 | 3.90 | 0.70 | 0.70 | 36 |
| Turbidity, NTU | 6.25 | 3.40 | 33.50 | 0.90 | 8.10 | 21 |
| Turbidity Hach Turbidimeter | 4.0 | 2.4 | 15.0 | 1.1 | 3.8 | 31 |
| Turbidity, Field | 2.7 | 2.3 | 4.6 | 0.3 | 1.4 | 9 |
| Turbidity, Lab, NTU | 7.2 | 2.7 | 50.0 | 1.8 | 13.6 | 12 |
| **Water Column Metals** | | | | | | |
| Lithium, Total, μg/L | 206 | 206 | 300 | 112 | 133 | 2 |
| Fe, Total, μg/L | 158 | 180 | 240 | 72 | 69 | 5 |
| Manganese, μg/L | 33.61 | 24.02 | 57.47 | 15.29 | 18.83 | 5 |
| Magnesium, Total, μg/L | 4,538 | 4,730 | 6,030 | 2,660 | 1,654 | 4 |

**Table 2.12      In-stream water quality data at 6BSTO004.56 (1/90-6/04) (cont.)**

| Water Quality Constituent | Mean | Median | Max | Min | SD[1] | N[2] |
|---|---|---|---|---|---|---|
| **Sediment Metals** | | | | | | |
| Selenium, sed mg/kg | 6.0 | 6.0 | 10.0 | 2.0 | 5.7 | 2 |
| Thallium,  sed, mg/kg | 3.5 | 3.5 | 6.0 | 1.0 | 3.5 | 2 |
| Iron, sed, mg/kg | 15,361 | 15,900 | 19,900 | 9,930 | 3,552 | 7 |
| Mn, sed, mg/kg | 971 | 621 | 2,900 | 447 | 862 | 7 |
| Aluminum, sed, mg/kg | 7,730 | 8,460 | 11,000 | 2,430 | 3,023 | 7 |
| Chromium, sed, mg/kg | 15.8 | 15.8 | 21.0 | 7.9 | 3.5 | 10 |
| Copper, sed, mg/kg | 19.8 | 16.5 | 41.5 | 12.0 | 9.2 | 10 |
| Lead, sed, mg/kg | 16.7 | 15.3 | 31.0 | 5.2 | 6.8 | 10 |
| Nickel, sed, mg/kg | 18.1 | 19.0 | 23.0 | 9.5 | 4.6 | 11 |
| Zinc, sed, mg/kg | 52.8 | 57.0 | 88.0 | 17.6 | 19.1 | 11 |
| Arsenic, sed, mg/kg | 7.3 | 5.5 | 16.0 | 5.0 | 4.3 | 6 |

[1]SD:  standard deviation, [2]N:  number of sample measurements

**Table 2.13      Single sample in-stream water quality data at 6BSTO004.56 (8/2003).**

| Water Quality Constituent | Value |
|---|---|
| **Water Column Metals** | |
| Aluminum, μg/L | 5.46 |
| Arsenic, μg/L | 0.28 |
| Barium, μg/L | 33.00 |
| Calcium, μg/L | 29.00 |
| Chromium, μg/L | 0.17 |
| Copper, μg/L | 0.25 |
| Lithium, μg/L | 97.30 |
| Magnesium, μg/L | 6.30 |
| Manganese, μg/L | 21.00 |
| Nickel, μg/L | 0.30 |
| **Sediment Metals** | |
| Antimony, sed, mg/kg | 13.0 |
| Beryllium, sed, mg/kg | 1.0 |
| Lithium, sed, mg/kg | 15.6 |

**Table 2.14      In-stream water quality data at 6BSTO004.73 (3/95-9/98).**

| Water Quality Constituent | Mean | Median | Max | Min | SD[1] | N[2] |
|---|---|---|---|---|---|---|
| Conductivity, μmhos/cm | 140 | 115 | 260 | 90 | 66 | 6 |
| DO, mg/L | 11.2 | 11.2 | 13.2 | 9.6 | 1.2 | 6 |
| Field pH, std units | 7.4 | 7.5 | 8.2 | 6.2 | 0.7 | 6 |
| Temperature, Celsius | 12.0 | 11.4 | 20.9 | 5.4 | 5.5 | 6 |

[1]SD:  standard deviation, [2]N:  number of sample measurements

**Table 2.15    In-stream water quality data at 6BSTO005.26 (8/03-4/04).**

| Water Quality Constituent | Mean | Median | Max | Min | SD[1] | N[2] |
|---|---|---|---|---|---|---|
| Conductivity, μmhos/cm | 132 | 132 | 181 | 83 | 69 | 2 |
| DO, mg/L | 10.1 | 10.1 | 11.7 | 8.6 | 2.2 | 2 |
| Field pH, std units | 7.7 | 7.7 | 7.9 | 7.5 | 0.3 | 2 |
| Temperature, Celsius | 13.1 | 13.1 | 20.2 | 6.0 | 10.0 | 2 |

[1]SD:  standard deviation, [2]N:  number of sample measurements

**Table 2.16    In-stream water quality data at 6BSTO007.33 (8/03-4/04).**

| Water Quality Constituent | Mean | Median | Max | Min | SD[1] | N[2] |
|---|---|---|---|---|---|---|
| Conductivity, μmhos/cm | 120 | 120 | 139 | 100 | 28 | 2 |
| DO, mg/L | 10.0 | 10.0 | 11.7 | 8.4 | 2.3 | 2 |
| Field pH, std units | 7.6 | 7.6 | 7.6 | 7.6 | 0 | 2 |
| Temperature, Celsius | 10.3 | 10.3 | 14.3 | 6.3 | 5.7 | 2 |

## 2.5.2   Fish tissue and sediment results from Stock Creek

VADEQ performed special fish tissue and sediment sampling at station 6BSTO004.56 on Stock Creek in June 2002.  As a result, the Virginia Department of Health (VDH) issued a fish consumption advisory for Stock Creek due to contamination from polychlorinated biphenyls (PCBs) (Table 2.17).  No other parameter exceeded a VDH action level.  The sediment data is summarized in Tables 2.18 – 2.20.  More information on the VDH ban can be found at http://www.vdh.state.va.us/HHControl/TennesseeBigSandy.asp.

**Table 2.17    Fish tissue sampling results for PCBs from Stock Creek.**

| Station | Date | Fish Species | VDH PCB action level (ppb wet weight basis) | PCB (ppb wet weight basis) |
|---|---|---|---|---|
| 6BSTO004.56 | 6/19/2002 | Rainbow Trout | 50 | 56.37 |
| 6BSTO004.56 | 6/19/2002 | Brown Trout | 50 | 58.85 |
| 6BSTO004.56 | 6/19/2002 | White Sucker | 50 | 53.01 |

**Table 2.18     Special study sediment metals results from 6BSTO004.56 on June 19, 2002.**

| Metal | Consensus PEC[1] value (mg/kg) | Value (mg/kg) |
|---|---|---|
| Aluminum | NA[2] | 0.39 |
| Silver | NA | <0.02 |
| Arsenic | 33 | 3.76 |
| Cadmium | 4.98 | 0.11 |
| Chromium | 111 | 12.98 |
| Copper | 149 | 7.86 |
| Mercury | 1.06 | 0.03 |
| Nickel | 48.6 | 8.78 |
| Lead | 128 | 9.19 |
| Antimony | NA | <0.5 |
| Selenium | NA | <0.5 |
| Thallium | NA | <0.3 |
| Zinc | 459 | 11.01 |

[1]PEC - Probable Effect Concentration

[2]NA - the PEC value is not available for this parameter

**Table 2.19    Special study sediment organics results from 6BSTO004.56 on June 19, 2002.**

| Parameter | PEC[1] (µg/kg) | Value (µg/kg) |
|---|---|---|
| Total PAH[2] | 22,800 | 243.53 |
| High MW[3] PAH | NA[14] | 108.96 |
| Low MW PAH | NA | 134.57 |
| NAP[4] | 561 | 9.31 |
| NAP 2-Me[5] | NA | 27.99 |
| NAP 1-Me[6] | NA | 16.97 |
| Biphenyl | NA | 2.25 |
| NAP d-Me[7] | NA | 19.53 |
| naphthylene ace~ | NA | 0.25 |
| Naphthene ace~ | NA | 1.23 |
| NAP t-Me[8] | NA | 11.29 |
| Fluorine | 536 | 1.60 |
| PHH[9] | 1,170 | 24.47 |
| ATH[10] | 845 | 1.28 |
| PHH 1-Me | NA | 18.40 |
| FTH[11] | 2,230 | 7.56 |
| Pyrene | 1,520 | 7.76 |
| ATH benz(a) | 1,050 | 9.01 |
| Chrysene | 1,290 | 10.42 |
| FTH benzo(b) | NA | 9.02 |
| FTH benzo(k) | NA | 5.14 |
| pyrene benzo(e) | NA | 9.18 |
| pyrene benzo(a) | 1,450 | 8.02 |
| Perylene | NA | 29.81 |
| pyrene IND[12] | NA | 4.19 |
| ATH db(a,h)[13] | NA | 1.61 |
| perylene benzo(ghi) | NA | 7.21 |

[1]PEC Probable Effect Concentration, [2]PAH Polyaromatic hydrocarbon, also polynuclear aromatic hydrocarbons (PNAs), [3] MW Molecular Weight, [4] NAP Naphthalene, [5] NAP 2-Me Methyl, [6] NAP 1-Me Methyl, [7] NAP d-Me, [8] 2,3,5 – Trimethyl, [9] Phenanthrene, [10] Anthracene, [11] Fluoranthene, indeno, [12] (1,2,3-cd), [13] dibenzo (a,h), [14] NA - the PEC value is not available for this parameter

**Table 2.20    Special study sediment PCB and pesticide results from 6BSTO004.56 on June 19, 2002.**

| Parameter | PEC[1] (µg/kg) | Value (µg/kg) |
|---|---|---|
| Total PCB[2] | 50 | 1.47 |
| Sum DDT[3] | 62.9 | 0.70 |
| Total DDT[4] | 572 | 0.70 |
| OCDD[5] | None | 0.06 |

[1]PEC Probable Effect Concentration, [2]Total PCB denotes sum of polychlorinated biphenyl congeners, [3]Total DDT denotes sum of isomers of DDE, DDD, and DDT, [4]Total DDT denotes sum of isomers of DDE, DDD, and DDT, [5] OCDD Octachlorodibenzodioxin

VADEQ periodically collected sediment metals data at 6BSTO004.56 during routine monitoring events.  This data was summarized in Table 2.12.  Metals that have established PEC values are compared to them in Table 2.21.

**Table 2.21    Sediment metals at VADEQ station 6BSTO004.56.**

| Metal | PEC[1] | Maximum | N[2] |
|---|---|---|---|
| Chromium, sed, mg/kg dry wgt | 111 | 21.0 | 10 |
| Copper, sed, mg/kg dry wgt | 149 | 41.5 | 10 |
| Lead, sed, mg/kg dry wgt | 128 | 31.0 | 10 |
| Nickel, sed, mg/kg dry wgt | 48.6 | 23.0 | 11 |
| Zinc, sed, mg/kg dry wgt | 459 | 88.0 | 11 |

[1]PEC Probable Effect Concentration, [2]Number of samples

## 2.5.3  Dissolved metals results from Stock Creek

Water column dissolved metals were sampled by the VADEQ at station 6BSTO004.56 in August 2003 and the results were below the hardness-based water quality standard (WQS) (Table 2.22) for metals that have an approved WQS.

**Table 2.22      Dissolved metals at VADEQ station 6BSTO004.56, as measured on August 26, 2003.**

| Metal | Standard μg/L | Value μg/L |
|---|---|---|
| Aluminum | NA | 5.46 |
| Arsenic | 150 | 0.28 |
| Barium | NA | 33 |
| Chromium | 4.0 | 0.17 |
| Copper | 17.0 | 0.25 |
| Nickel | 180.0 | 0.30 |

NA - Virginia has no water quality standard

## 2.6   Water Quality Issues in Stock Creek

The Chemetall Foote Corporation Sunbright facility operated at the site of the former Cyprus Foote Mineral Company, but it is now closed and the plant site has been reclaimed. Located approximately two miles northeast of the Town of Duffield, the facility produced lithium hydroxide off and on between 1952 and 1996 (Faulkner and Flynn, 2003). Lithium hydroxide was produced at the Sunbright facility by mining limestone on the site and combining it with spodumene (a mineral containing lithium). The process resulted in a very large quantity of calcium aluminum silicate $(Ca_3Al_2(SiO_4)_3)$ that was stockpiled on the site. From the mid 1970s through the early 1980s, special studies by the State Water Control Board (SWCB) staff confirmed that the benthic community was depressed below the Chemetall Foote Corporation Sunbright site. The only suspected pollutant was lithium that was discharged by the Sunbright facility to Bishop Creek (a tributary to Stock Creek). There is no standard or screening value for lithium. A technical evaluation of Stock Creek prepared by Faulkner and Flynn (2003) for the Chemetall Foote Corporation noted that there were 11 acute and four chronic lithium aquatic life toxicity studies. Acute endpoints ranged from 17 – 186 mg/L and chronic endpoints ranged from 5.4 – 9.0 mg/L. A comprehensive Qualitative Biological Survey (B83-003) was performed by the SWCB on September 28, 1982 (Shelor, 1983). Four stations on Stock Creek were sampled in addition to an upstream control. The report concluded that there was benthic impairment at the four sampling sites located on Stock Creek downstream of the Bishop Creek confluence. The most impacted site was at river mile 2.45, approximately two miles downstream of the discharge. A total lithium concentration of 11.00 mg/L was measured at this site on the same day that benthic

sampling was performed. This represented nearly a tenfold increase from the upstream sampling stations closer to the known source. The benthic community improved slightly at the most downstream sampling station located at river mile 0.45. The total lithium concentration was 7.0 mg/L and the report speculated that several tributaries between the two sampling sites provided dilution. The SWCB continued to sample total lithium concentrations at river mile 4.73 (just below the Bishop Creek confluence) and river mile 2.49 (near Natural Tunnel) until March 1984 to rule out the possibility of a second lithium pollution source. The results were consistent with each other (Table 2.23 and Figure 2.3). It is possible that the large spike measured on 9/28/1982 represented the tail end of a slug that was released from the processing plant and not an additional pollution source. It is clear from the data collected in the early 1980s that maximum total lithium concentrations occasionally exceeded the values found in the chronic toxicity range cited in the Faulkner and Flynn report (2003).

**Table 2.23    Statistical summary of lithium collected at VADEQ monitoring stations 6BSTO004.56 and 6BSTO002.49 between 9/1982 – 3/1984.**

| Station | Average (mg/L) | Maximum (mg/L) | Minimum (mg/L) | Median (mg/L) | Number | Chronic Range* (mg/L) |
|---------|---------|---------|---------|---------|--------|---------|
| 6BSTO002.49 | 2.37 | 11.00 | 0.13 | 1.00 | 11 | 5.4 - 9.0 |
| 6BSTO004.56 | 1.86 | 9.60 | 0.10 | 0.81 | 13 | 5.4 - 9.0 |

* Chronic range from a technical report by Faulkner and Flynn for the Chemetall Foote Corporation, 2003.
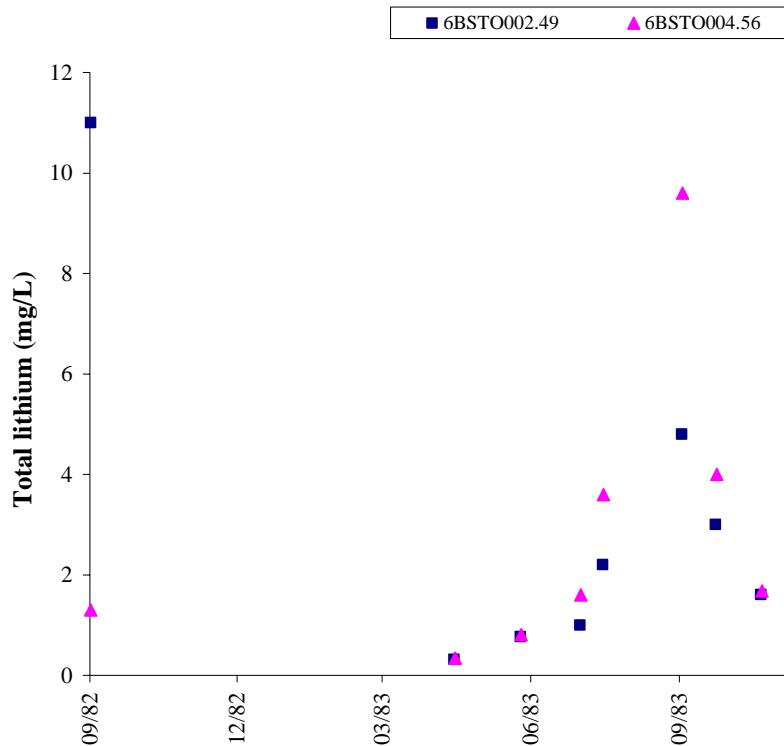
**Figure 2.3**     **Total lithium concentrations at VADEQ monitoring stations 6BSTO002.49 and 6BSTO004.56.**

Follow up benthic monitoring at 6BSTO000.45 in fall 1992 documented that there had been considerable improvement in the benthic community. The VASCI score was well above the impairment threshold of 61.3.

All operations at the Sunbright site were closed down between 1994 and 1997. Significant remediation work was completed as part of the closure activities, including the following:

- Excavation and disposal of approximately 120,000 cubic yards of calcium aluminum silicate from two waste piles and a sinkhole located just north of the facility.

- A Spodumene-Lime Tailings Pile (SLTP) was capped in 1995 with a composite landfill-type cover system.

- The main plant site and a stormwater sedimentation pond located east of the plant site were demolished and all debris was disposed of in an approved landfill.

- A "solid waste" filter cake in the mine works area was determined by VADEQ to be "inert waste" and was closed in place.

According to the report by Faulkner and Flynn (2003), the closure activities have been successful by reducing the amount of lithium and aluminum being discharged to the receiving stream via runoff from the plant site and local groundwater seeps, and stabilizing the discharge of lithium and aluminum from groundwater to the receiving stream from 1997 to 2003.  In addition, the following took place:

- Lithium concentrations measured at three offsite drinking wells remained well below the Residential Risk-Based Concentration for Tap Water (730 $\mu$g/L).

- Dr. Donald Cherry from Virginia Tech conducted Whole Effluent Toxicity (WET) testing from three samples collected in the Bishop Creek/Stock Creek mixing zone that showed no acute or chronic effects at 100% strength.  The samples were collected between August 26 and August 30, 2003.

- A benthic macroinvertebrate study conducted by Dr. Donald Cherry on June 10, 2003 at six locations in Stock Creek showed a balanced and diverse benthic population with adequate numbers of the sensitive taxa.

The lithium data contained in Appendix 1 of the Faulkner and Flynn report supports the first conclusion that lithium concentrations were lower during the post-closure period than the time period before closure was completed (Figure 2.4).  Since November 1996, no lithium concentrations have been measured that exceeded the chronic toxicity range (Faulkner & Flynn, 2003) at the Stock Creek monitoring station located at the highway marker (approximately ½ mile below the Bishop Creek confluence).
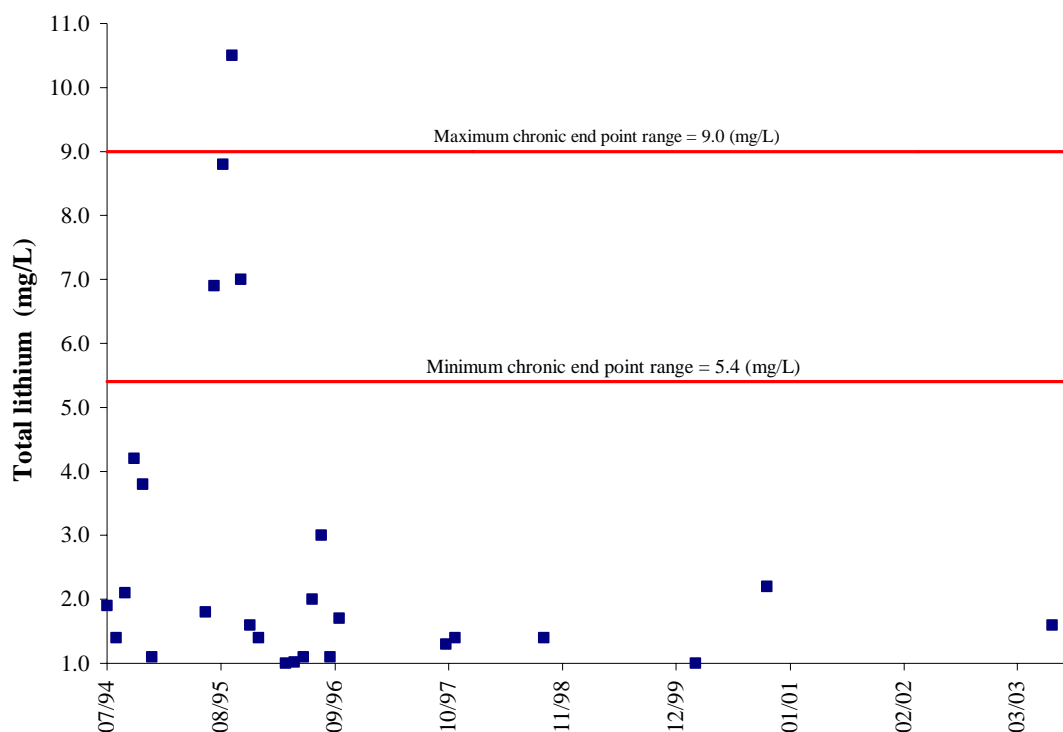
**Figure 2.4    Total lithium concentrations collected by Chemetall Foote Corp. at the highway marker on Stock Creek (from Faulkner and Flynn, 11/2003)**.

Special toxicity testing sampling was performed by VADEQ at monitoring station 6BSTO004.56 in November 2004.  The sample was analyzed by the EPA Wheeling, West Virginia Biology Group and no toxicity was found.

## 2.7   VPDES permitted discharges in the Stock Creek Watershed

There is one active VPDES permitted discharge in the Stock Creek watershed (Table 2.24 and Figure 2.5).  As discussed above, the Sunbright facility is closed; however, continued operation of a pH neutralization station for outfall 401 is necessary to protect the receiving waters.  The other outfalls require stormwater runoff monitoring.

**Table 2.24    VPDES permitted discharges in the Stock Creek watershed.**

| Permit No | Facility Name | Class | Design Flow (MGD) | Receiving Stream | River Mile | TYPE |
|---|---|---|---|---|---|---|
| VA0052655 | Chemetall Foote Corp. – Sunbright | Active | 0.200 | 004 – Stock Creek<br>401 – Bishop Creek<br>003 – N.F. Clinch River X-Trib | 004 – 5.26<br>401 – 0.20<br>003 – 23.5 | VPDES Individual |
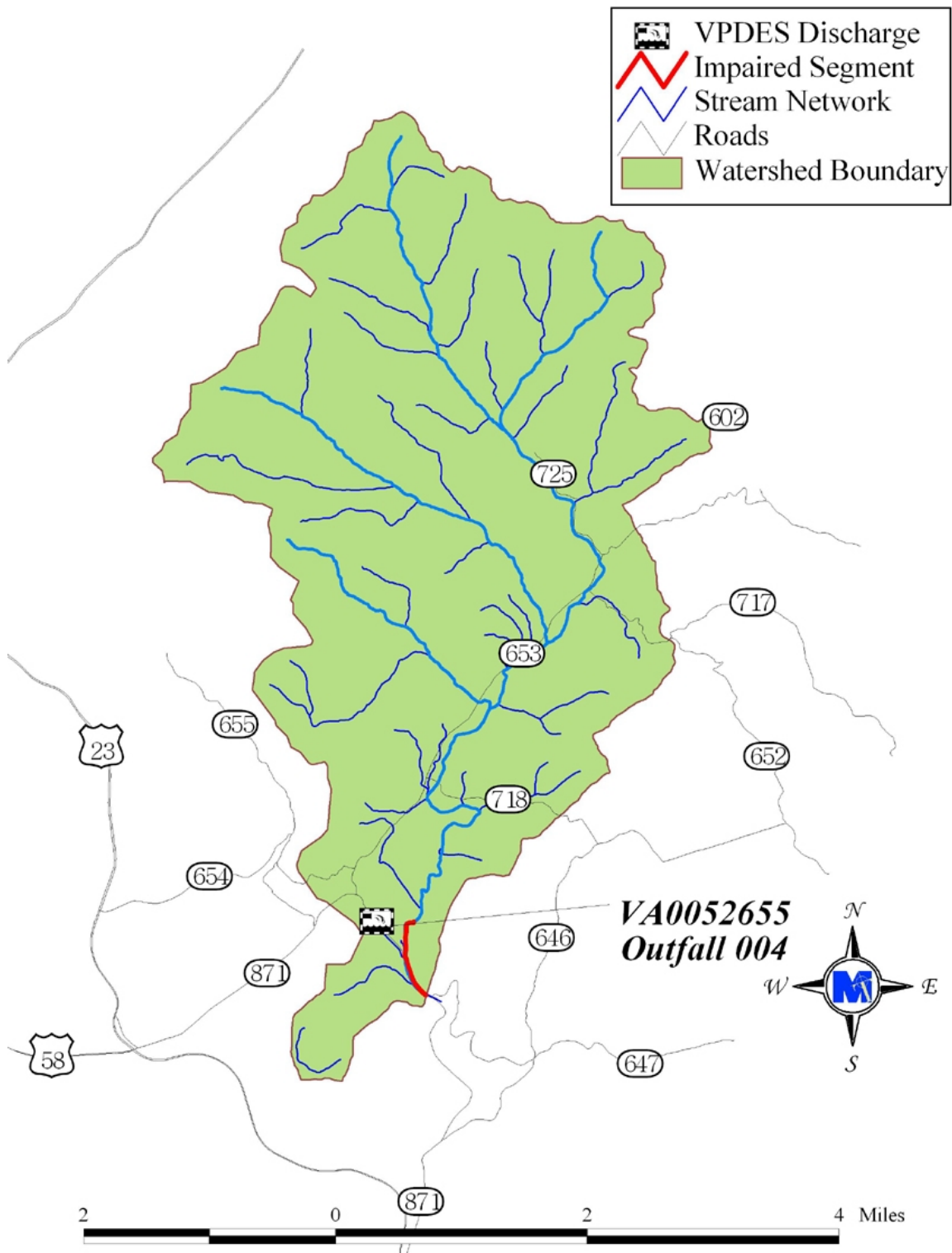
**Figure 2.5     VPDES permitted discharge in the Stock Creek watershed.**

# 3. TMDL ENDPOINT: STRESSOR IDENTIFICATION AND REFERENCE WATERSHED SELECTION FOR STOCK CREEK

## 3.1 Stressor Identification

Stock Creek is located in Scott County, Virginia, east of the Town of Duffield. It flows in a southerly direction for approximately 12.8 miles before its confluence with the Clinch River. The impaired section begins at river mile 5.22 and ends at river mile 4.53 for a total of 0.69 stream miles. It basically brackets the former Chemetall Foote Corp. – Sunbright facility. As was discussed in Chapter 2, this facility produced lithium hydroxide on 509 acres. Stock Creek is a third order stream at the impaired section.

All available VADEQ data were analyzed for parameters that exceeded an established water quality criteria or screening value. For parameters without established water quality criteria or screening values a 90th percentile screening value was used. The 90th percentile screening values were calculated from 49 monitoring stations in Southwest Virginia on third and fourth order streams that were used as benthic reference stations or were otherwise found not to have a benthic impairment based on the most recent sampling results. The 90th percentile screening values were used to develop a list of possible stressors. For a parameter to become a probable stressor additional information was required such as benthic habitat and metrics and scientific references documenting problems for aquatic life. Graphs are shown for parameters that exceeded a 90th percentile value in more than 10% of the samples collected within the impaired segment, or if the parameter had extreme values. If a parameter does not exceed a water quality standard, screening value in more than 10% of the samples collected, or does not have excessive values, median values will be shown for each monitoring station from downstream to upstream. Data for parameters with more than one but less than nine data points can be found summarized in section 2.5.1. The presence of nine values was selected as a cutoff in order to avoid using data from stations that were not sampled during different seasons of the year or different flow regimes in Stock Creek. However, all data was reviewed to ensure consistency with expected value ranges in the stream.

TMDLs must be developed for a specific pollutant(s). Benthic assessments are very good at determining if a particular stream segment is impaired or not but they usually do not provide

enough information to determine the cause(s) of the impairment. The process outlined in the Stressor Identification Guidance Document (EPA, 2000) was used to separately identify the most probable stressor(s) for Stock Creek. A list of candidate causes was developed from published literature, VADEQ, and input from Virginia's Department of Mines, Minerals, and Energy, Division of Mined Land Reclamation (DMLR) staff. Chemical and physical monitoring data provided evidence to support or eliminate potential stressors. Individual metrics for the biological and habitat evaluation were used to determine if there were links to a specific stressor(s). Land use data, as well as a visual assessment of conditions along the stream, provided additional information to eliminate or support candidate stressors. The potential stressors are: sediment, toxics, low dissolved oxygen, nutrients, pH, metals, conductivity/total dissolved solids, temperature, and organic matter.

The results of the stressor analysis for Stock Creek are divided into three categories:

> **Non-Stressor(s)**: Those stressors with data indicating normal conditions, without water quality standard violations, or without the observable impacts usually associated with a specific stressor, were eliminated as possible stressors (Table 3.1).

> **Possible Stressor(s)**: Those stressors with data indicating possible links, but inconclusive data, were considered to be possible stressors (Table 3.2).

> **Most Probable Stressor(s)**: The stressor(s) with the most consistent information linking it with the poorer benthic and habitat metrics was considered to be the most probable stressor(s) (Table 3.3).

## 3.2  Non-Stressors

**Table 3.1       Non-Stressors in Stock Creek.**

| Parameter | Location in Document |
|---|---|
| Dissolved oxygen | Section 3.2.1 |
| Temperature | Section 3.2.2 |
| Nutrients | Section 3.2.3 |
| Toxics | Section 3.2.4 |
| Metals (except lithium) | Section 3.2.5 |
| pH | Section 3.2.6 |
| Organic matter | Section 3.2.7 |
| Conductivity/total dissolved solids | Section 3.2.8 |

### 3.2.1  Low Dissolved Oxygen

Dissolved oxygen (DO) concentrations were well above the water quality standard at VADEQ monitoring station 6BSTO004.56 (Figure 3.1).  Dissolved oxygen samples were collected before sunrise (5:50 am) at station 6BSTO007.33 on August 26, 2003 and just after sunrise (7:30 am) at station 6BSTO004.56 to determine if dissolved oxygen concentrations remained above water quality standards during the night.  Oxygen demand is highest during the early morning hours during the summer months and this can be a time when water quality standards' violations occur.  The measurements were 8.39 and 7.95 mg/L, respectively, indicating that dissolved oxygen concentrations remain well above the water quality standards even during the critical time periods just before daylight.  Low dissolved oxygen concentrations are considered a non-stressor.
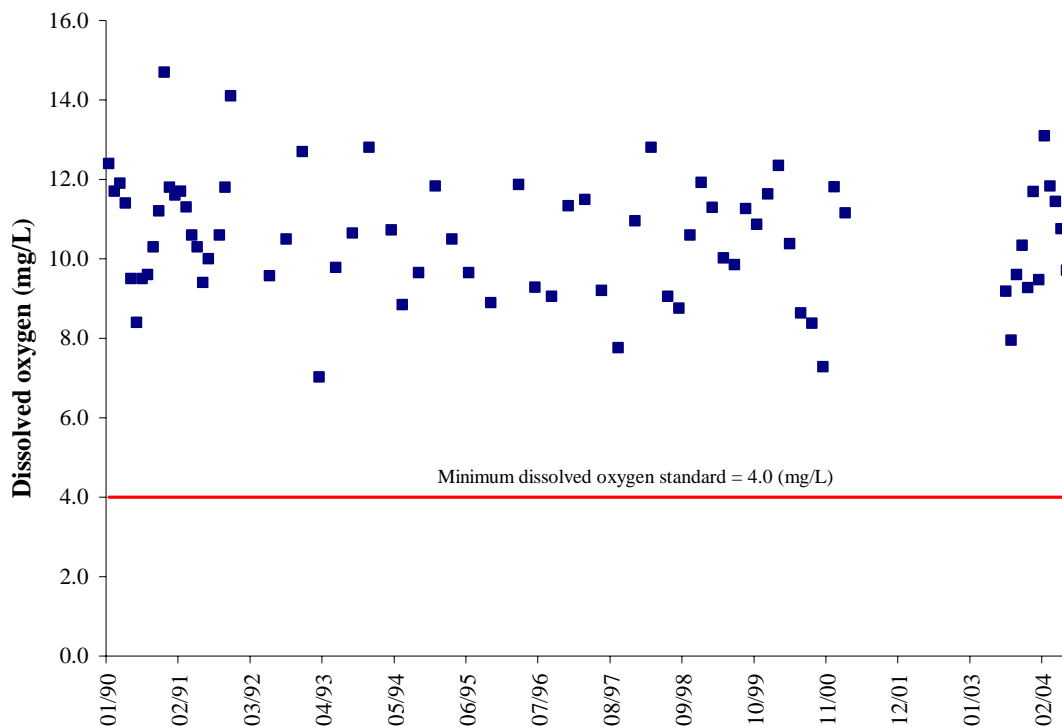


**Figure 3.1    Dissolved oxygen concentrations at VADEQ monitoring station 6BSTO004.56.**

## 3.2.2  Temperature

The maximum temperature recorded in Stock Creek was $24.1^{o}$C at VADEQ station 6BSTO004.56, which is well below the state standard of $31^{o}$C for the mountain zone waters (Figure 3.2).
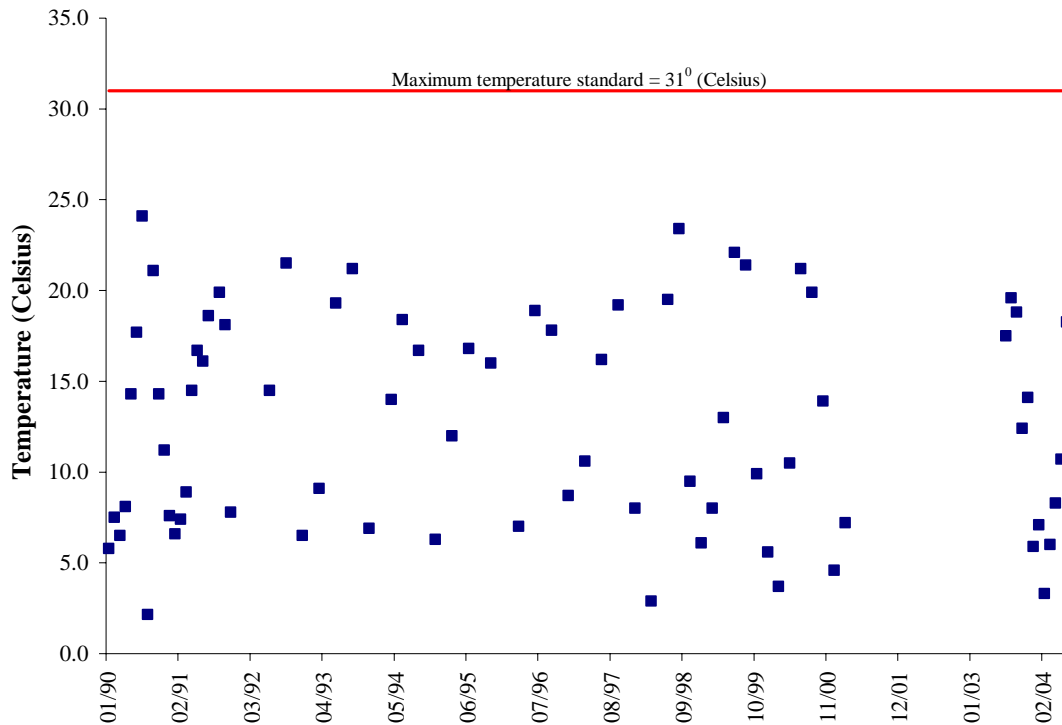


**Figure 3.2      Temperature measurements at VADEQ station 6BSTO004.56.**

## 3.2.3  Nutrients

Median total phosphorus (TP) concentrations at VADEQ station 6BSTO004.56 were below the VADEQ assessment screening value of 0.2 mg/L (Figure 3.3).
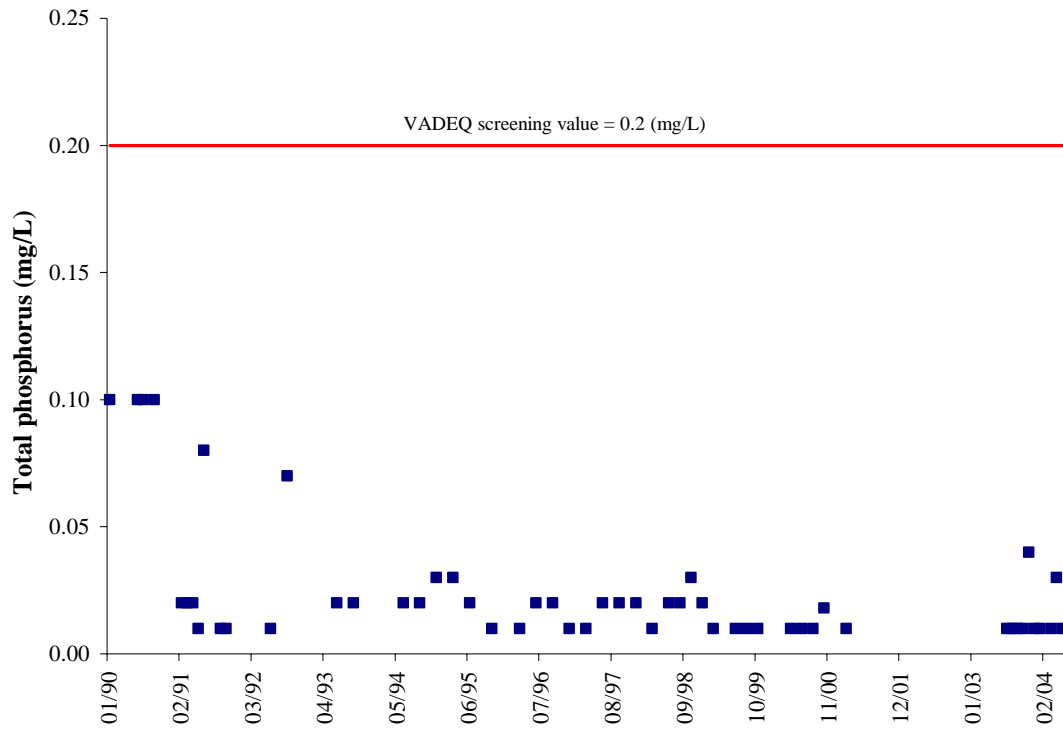
**Figure 3.3      Total phosphorus concentrations at VADEQ station 6BSTO004.56.**

Nitrate nitrogen ($NO_3$-N) concentrations are well within acceptable levels, with values never exceeding the 90th percentile screening value of 1.23 mg/L (Figure 3.4).
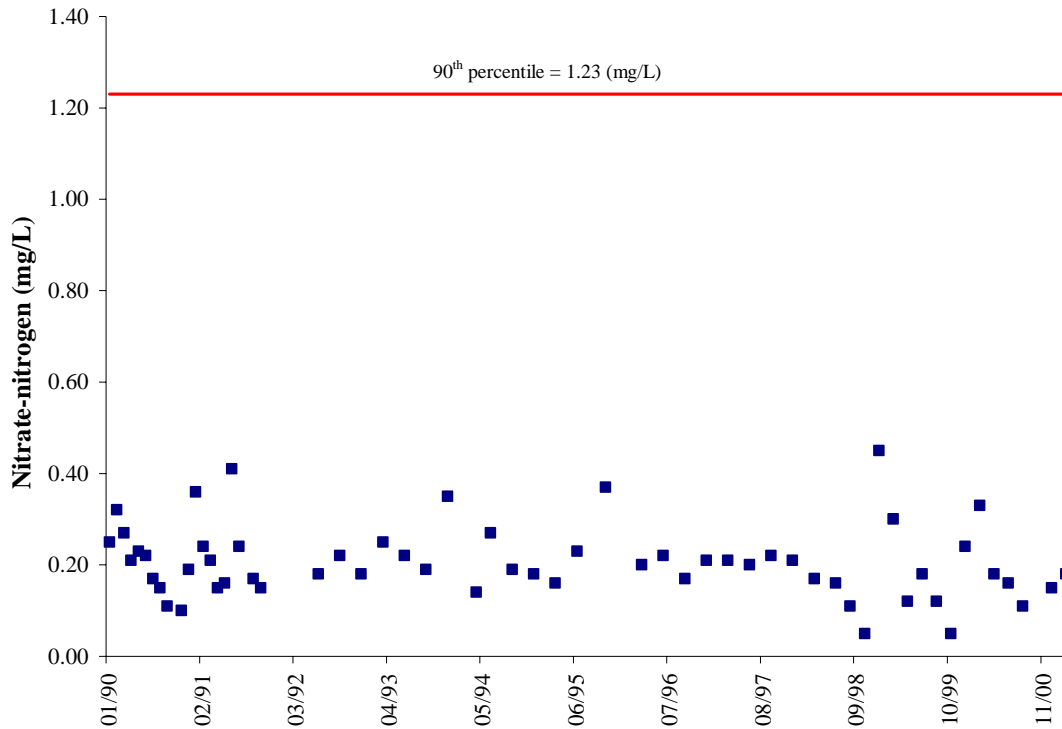
**Figure 3.4**      **Nitrate nitrogen concentrations at VADEQ station 6BSTO004.56.**

### 3.2.4 Toxics

There were only four total ammonia ($NH_3/NH_4$) concentrations at VADEQ station 6BSTO004.56 and the highest value was 0.13 mg/L, which was well below the chronic water quality standard. Total chloride concentrations were also extremely low (Figure 3.5).
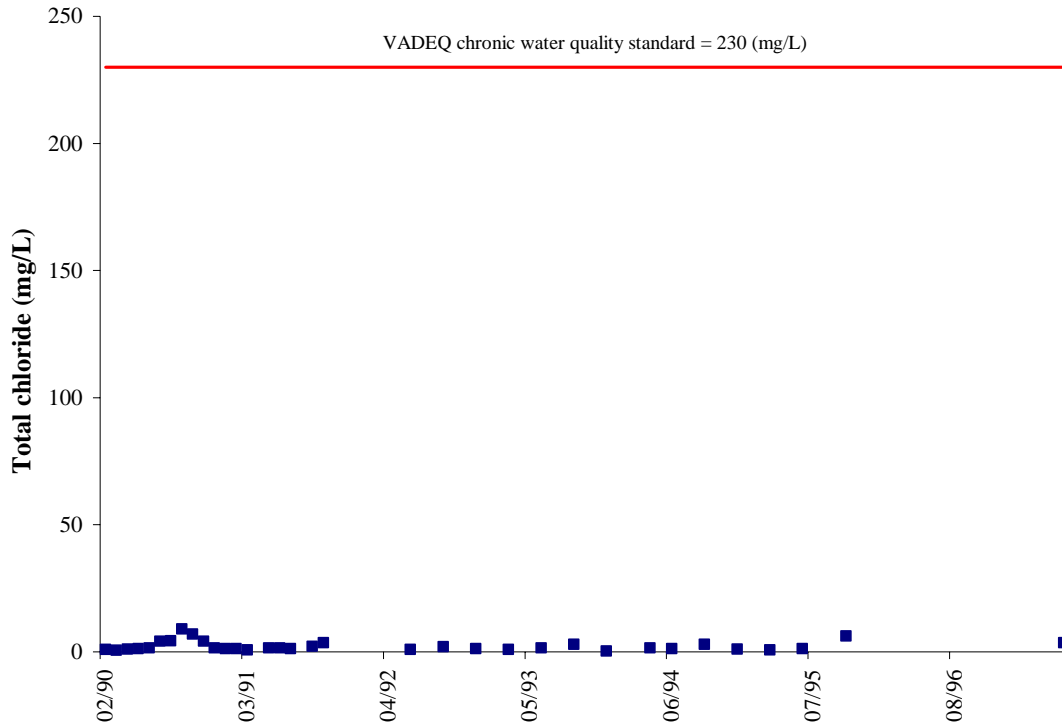
**Figure 3.5        Total chloride concentrations at VADEQ station 6BSTO004.56.**

Fish tissue and sediment PCBs, organics, and pesticides were collected at VADEQ station 6BSTO004.56 on June 19, 2002.  PCBs exceeded the VDH action level of 50 ppb in rainbow trout, brown trout, and white sucker (Table 2.16).  The VDH has issued a fish consumption advisory from the Rt. 650 bridge above Natural Tunnel downstream to the Clinch River confluence (approximately 5 miles).  More information on the VDH action can be found at http://www.vdh.state.va.us/HHControl/fishingadvisories.asp.    All sediment values at this monitoring station were below the established probable effect concentration (PEC) (MacDonald et al., 2000) values.

## 3.2.5  Metals

VADEQ performed monitoring for metals dissolved in the water column, metals in the sediment, and metals in fish tissue at monitoring station 6BSTO004.56.  Section 2.5.2 noted that sediment metals were below the PEC, though not all of the metals sampled have a PEC value.  Water column dissolved metals were sampled in August 2003 and the results were

below the hardness-based WQS for metals that have an approved WQS. A table comparing dissolved metals to the appropriate WQS was included in section 2.5.3.

Based on the results of the dissolved metals, sediment metals, and fish tissue metals data, metals (with the exception of lithium) are considered non-stressors.

### 3.2.6  pH

Field pH was measured at three VADEQ water quality monitoring sites. One value from November 1990 exceeded the maximum water quality standard of 9.0 std units (Figure 3.6). Because there have been no reoccurrences of high field pH values, it is considered a non-stressor.



**Figure 3.6      Field pH values at VADEQ station 6BSTO004.56.**

### 3.2.7  Organic matter

Several different parameters were used to determine if organic matter in the stream was impacting the benthic macroinvertebrate community. Biochemical oxygen demand ($BOD_5$)
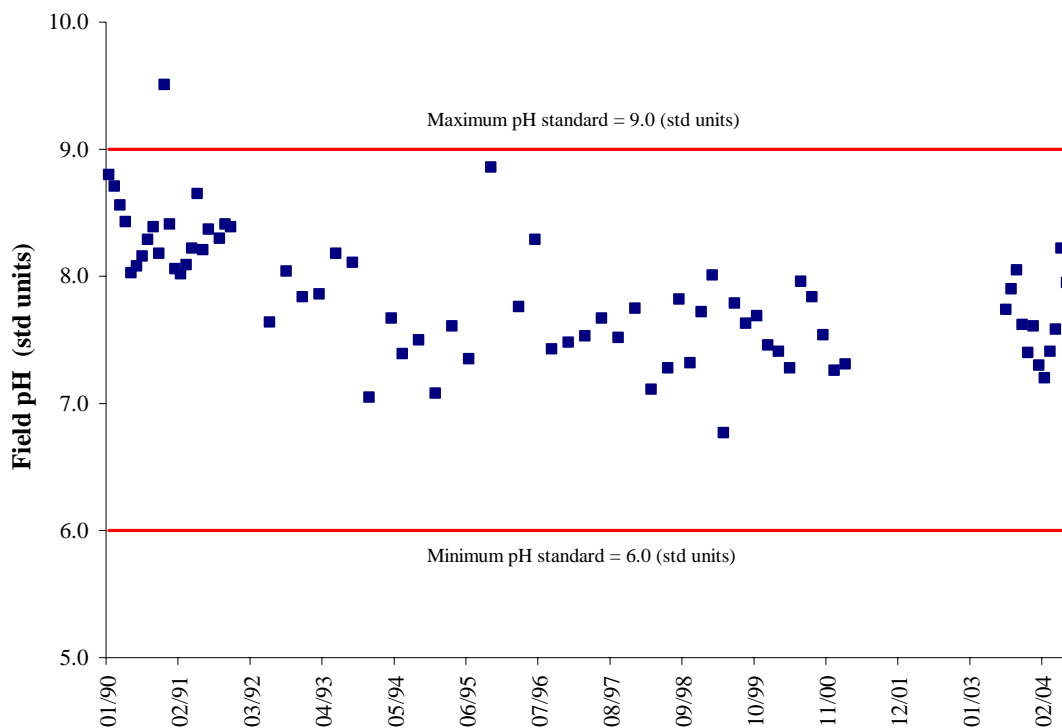
provides an indication of how much dissolved organic matter is present. Total organic carbon (TOC), chemical oxygen demand (COD), and total organic solids (TVS) provide an indication of dissolved organic matter. Organic suspended solids (VSS) provide an indication of particulate organic matter in a stream. Concentrations of $BOD_5$, TOC, COD, TVS and VSS were relatively low at VADEQ monitoring station 6BSTO004.56 (Figure 3.7 through Figure 3.11). Therefore, organic matter is considered a non-stressor.
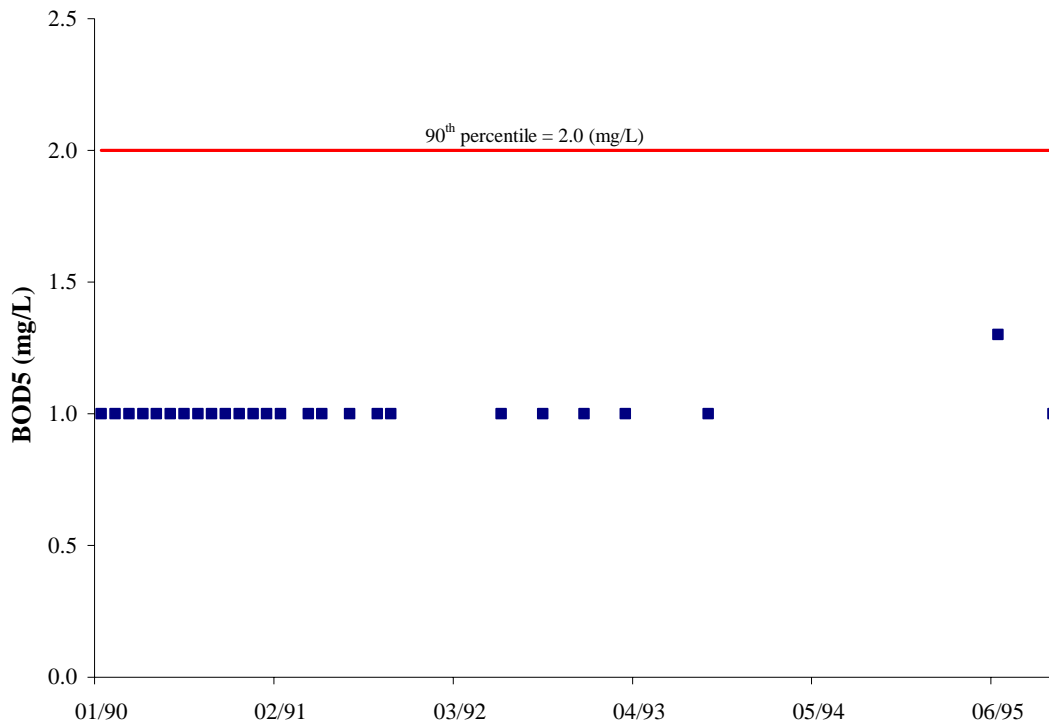


**Figure 3.7** **$BOD_5$ concentrations at VADEQ monitoring station 6BSTO004.56.**
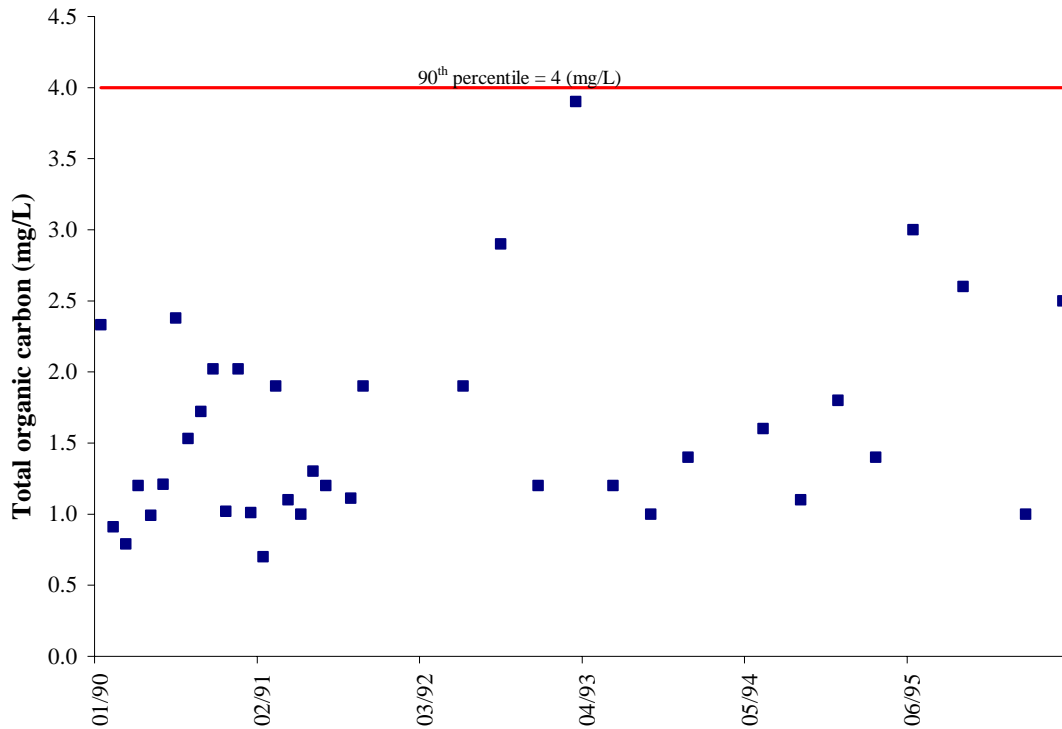
**Figure 3.8      TOC concentrations at VADEQ station 6BSTO004.56.**
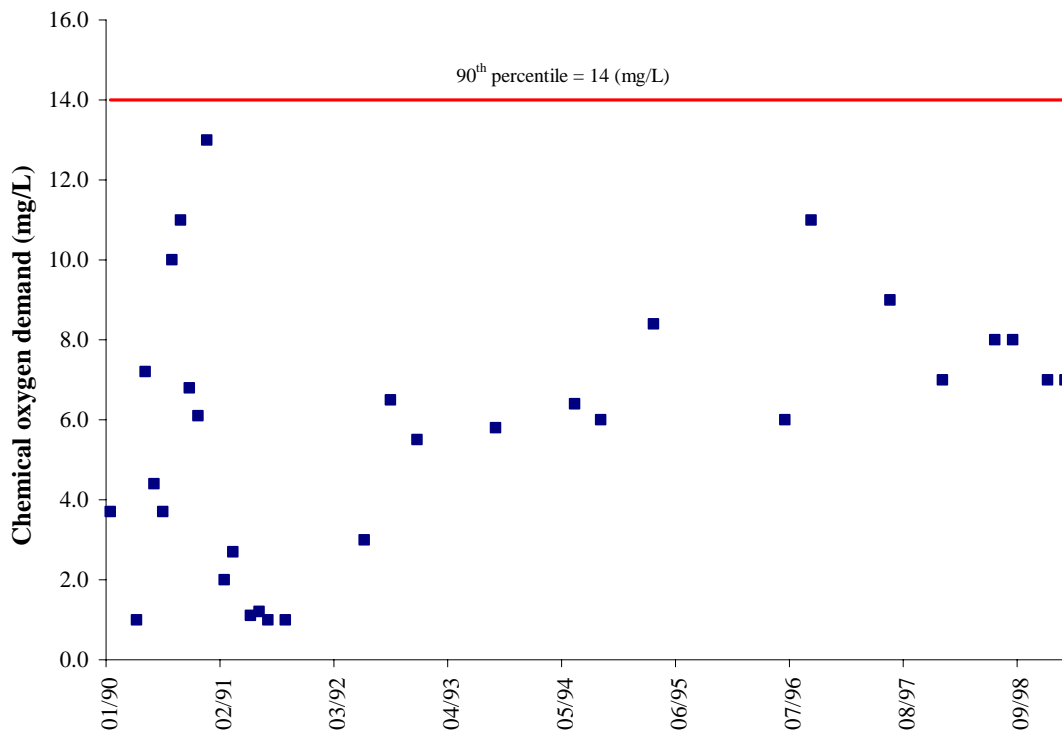


**Figure 3.9      COD concentrations at VADEQ station 6BSTO004.56.**
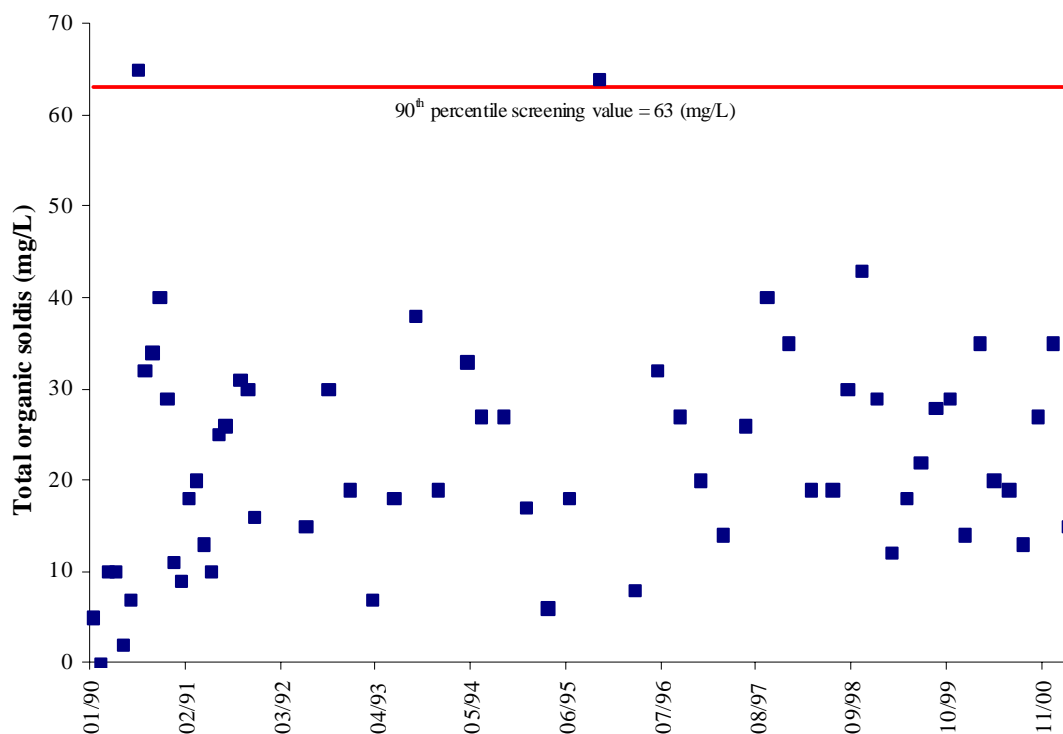
**Figure 3.10    Total organic solids concentrations at VADEQ station 6BSTO004.56.**
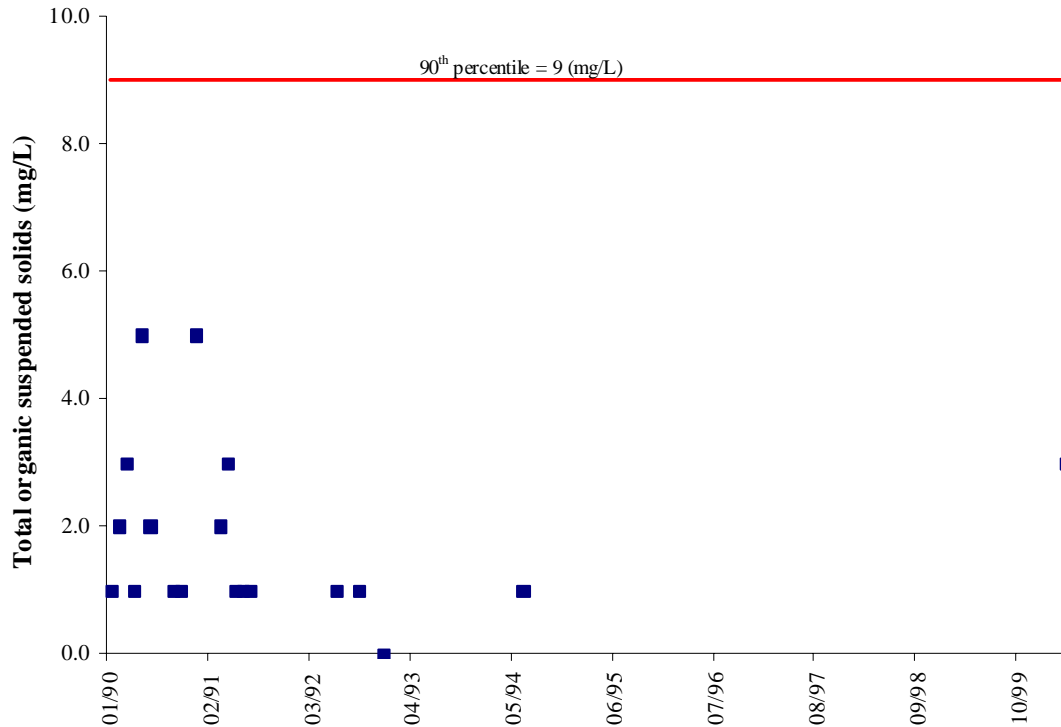
**Figure 3.11    Organic   suspended   solids   concentrations   at   VADEQ   station 6BSTO004.56.**

### 3.2.8  Conductivity and total dissolved solids

Conductivity is a measure of the electrical potential in the water based on the ionic charges of the dissolved compounds that are present.  Since total dissolved solids (TDS) is a measure of the concentration of dissolved salts plus dissolved metals, minerals, and organic matter, there is often a correlation with conductivity.  While the state of Virginia has no water quality standard for either conductivity or TDS, standards set by other states have values varying between 1,000 and 1,500 for either parameter.

Median conductivity values were less than 300 μmhos/cm at every station where measurements were made.  A 90th percentile screening value of 402 μmhos/cm was calculated from streams with non-impaired benthic communities in Southwest Virginia and no conductivity values exceeded it.  Median conductivity values for VADEQ station 6BSTO004.56 in Stock Creek are shown in Figure 3.12.

TDS is a measure of the actual concentration of the dissolved ions, dissolved metals, minerals, and organic matter in water. Dissolved ions can include sulfate, calcium carbonate, chloride, etc. TDS concentrations were all below the 90th percentile screening concentration of 260 mg/L. Figure 3.13 shows TDS concentrations at 6BSTO004.56.
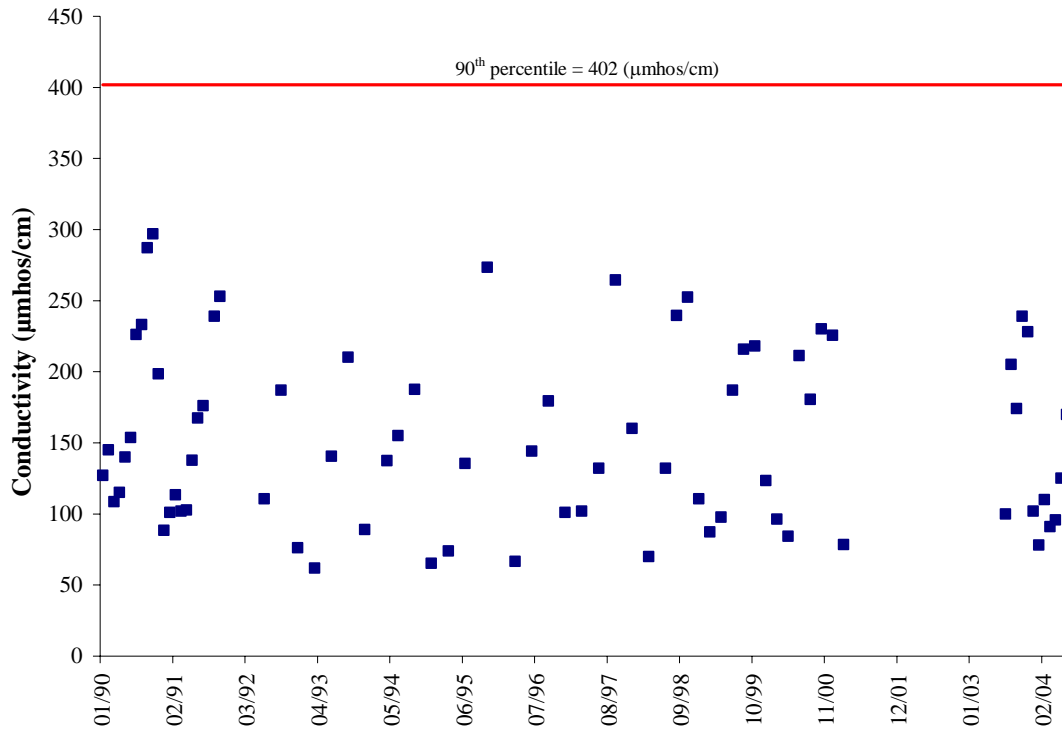


**Figure 3.12    Conductivity values at VADEQ station 6BSTO004.56.**
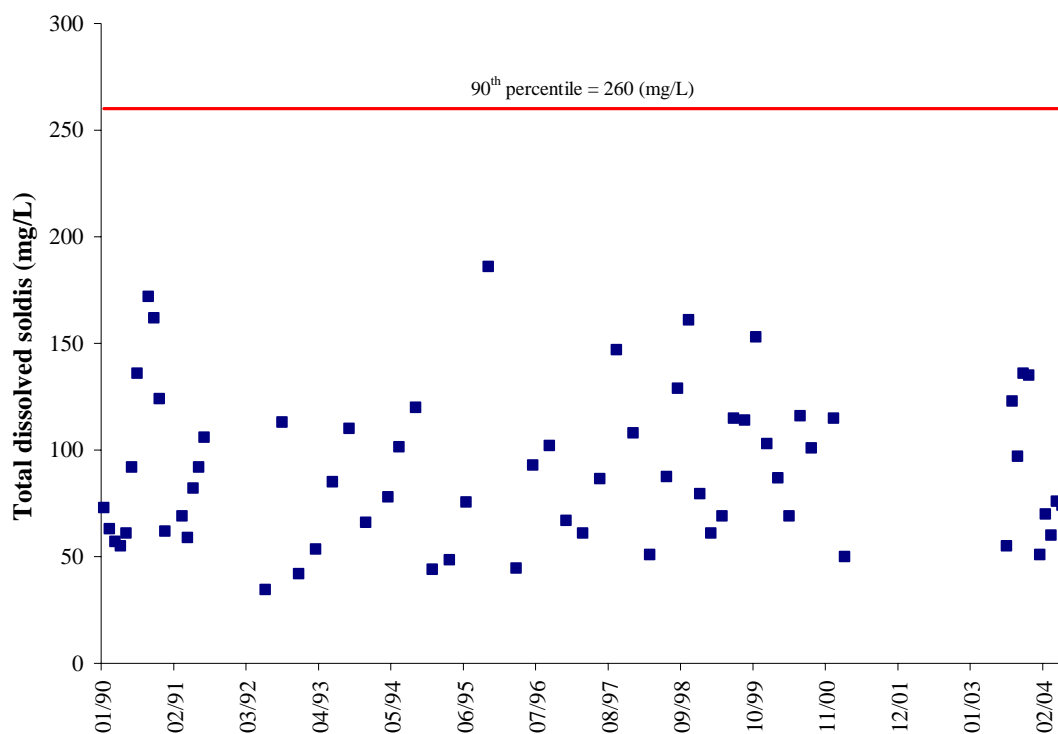
**Figure 3.13    TDS concentrations at VADEQ station 6BSTO004.56.**

## 3.3  Possible Stressors

**Table 3.2        Possible Stressors in Stock Creek.**

| Parameter | Location in Document |
|-----------|---------------------|
| Lithium | 3.3.1 |

### 3.3.1  Lithium

The closed Chemetall Foote Corp – Sunbright facility, which is located close to Stock Creek, produced lithium hydroxide (see section 2.6).  Special studies by the Virginia SWCB confirmed an impaired benthic community in Stock Creek in the late 1970s and early 1980s.  The cause of the impairment was deemed to be unusually high in-stream lithium concentrations.  The plant was closed in the mid 1990s and remediation of the site and the waste piles was completed in late 1997.  No in-stream lithium concentrations have been measured that exceed the chronic endpoint range discussed in Faulkner and Flynn (2003) since remediation was completed.  Groundwater and spring seeps around the facility have

higher lithium concentrations than does normal groundwater, but concentrations have declined and/or remained constant since late 1997. Total lithium concentrations were measured by the VADEQ at station 6BSTO004.56 on two occasions, August 2003 (0.3 mg/L) and April 2004 (0.112 mg/L). Dissolved lithium was measured at the same monitoring station in April 2004 (0.0973 mg/L). Therefore, the lithium present in Stock Creek from the former lithium hydroxide plant is deemed not to be impacting the benthic macroinvertebrate population in Stock Creek due to the low concentrations. As noted at the end of section 2.6, special toxicity samples collected by the VADEQ in November 2004 showed no toxicity. However, due to the presence of lithium in the groundwater around the former plant site, it is considered a possible stressor.

## *3.4  Probable Stressors*

**Table 3.3        Probable Stressors in Stock Creek.**

| Parameter | Location in Document |
|---|---|
| Sediment | 3.4.1 |

### 3.4.1  Sediment

The median scores for embeddedness were in the optimal and suboptimal categories at VADEQ benthic monitoring station 6BSTO004.73. VADEQ benthic monitoring 6BSTO005.26 had a marginal score in the spring of 1998. Pool Sediment scores were marginal in the 1997, 1998 and 2004 benthic monitoring surveys at VADEQ station 6BSTO004.73. VADEQ benthic monitoring station 6BSTO005.26 had optimal sediment scores in 1998. Both the Pool Sediment and Embeddedness parameters provide an indication of sediment problems in the stream. Both stations had low scores for at least one of these parameters. It is also notable that the Bank Stability parameter had marginal scores at both of the benthic monitoring stations. Bank Stability is indicative of the erosion potential of the stream bank which can add significant amounts of sediment during high flows. Total suspended solids (TSS) concentrations were very low, but there was one spike of 77 mg/L in November 2003 (Figure 3.14). Due to the marginal Embeddedness and Pool Sediment scores and the spike in TSS concentrations in November 2003, sediment is considered a probable stressor in this analysis and it will be the target pollutant used to address the benthic impairment in Stock Creek.
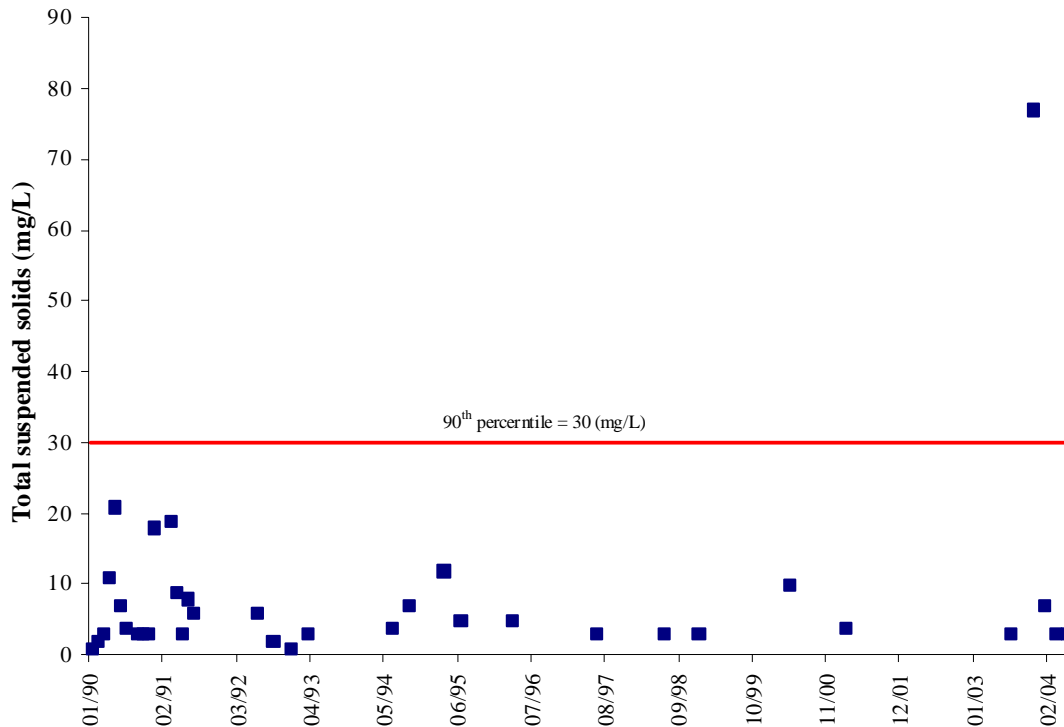
**Figure 3.14    TSS concentrations at VADEQ station 6BSTO004.56.**

## 3.5  *Trend and Seasonal Analyses*

In order to improve the TMDL allocation scenarios and, therefore, the success of implementation strategies, trend and seasonal analyses were performed on total suspended solids.  A Seasonal Kendall Test was used to examine long-term trends.  The Seasonal Kendall Test ignores seasonal cycles when looking for long-term trends.  This improves the chances of finding existing trends in data that are likely to have seasonal patterns. Additionally, trends for specific seasons can be analyzed.  For instance, the Seasonal Kendall Test can identify the trend (over many years) in dissolved oxygen levels during a particular season or month.  A seasonal analysis of water chemistry results was conducted using the Mood Median Test.  This test was used to compare median values of water quality in each season.

There was insufficient data to perform a Seasonal Kendall Test for long-term trends and a Moods Median Test for seasonality on total suspended solids.

## 3.6   Reference Watershed Selection

A reference watershed approach was used to estimate the necessary load reductions that are needed to restore a healthy aquatic community and allow the streams in the Stock Creek watershed to achieve their designated uses. The reference watershed approach is based on selecting a non-impaired watershed that has similar attributes, land use, soils, stream characteristics (*e.g.*, stream order, corridor, slope), area (not to be less than half, or more than twice, the size of the impaired watershed), and is in the same ecoregion as the impaired watershed.

The modeling process uses load rates in the non-impaired watershed as a target for load reductions in the impaired watershed. The impaired watershed is modeled to determine the current load rates and determine what reductions are necessary to meet the load rates of the non-impaired watershed.

A total of nine potential reference watersheds from the Central Appalachians ecoregion were selected for analysis that would lead to the selection of a reference watershed for Stock Creek (Figure 3.15). The potential reference watersheds were ranked based on quantitative and qualitative comparisons of watershed attributes (*e.g.*, land use, soils, slope, stream order, watershed size, etc.). Based on these comparisons, and after conferring with state and regional VADEQ personnel, the Stony Creek watershed (also located in Scott County) was selected as the reference watershed for Stock Creek. Tables 3.4 and 3.5 show Stock Creek and the potential reference streams along with the information used to compare them.

The Stony Creek watershed was the best fit based on watershed size, land use, and slope. Only the portion of Stony Creek watershed above the biological monitoring station was considered; as a result, the contributing area from Stony Creek was almost 94% of the area of Stock Creek watershed. This resulted in a minimum adjustment in the area of the reference watershed to match that of the impaired watershed, which is desired.
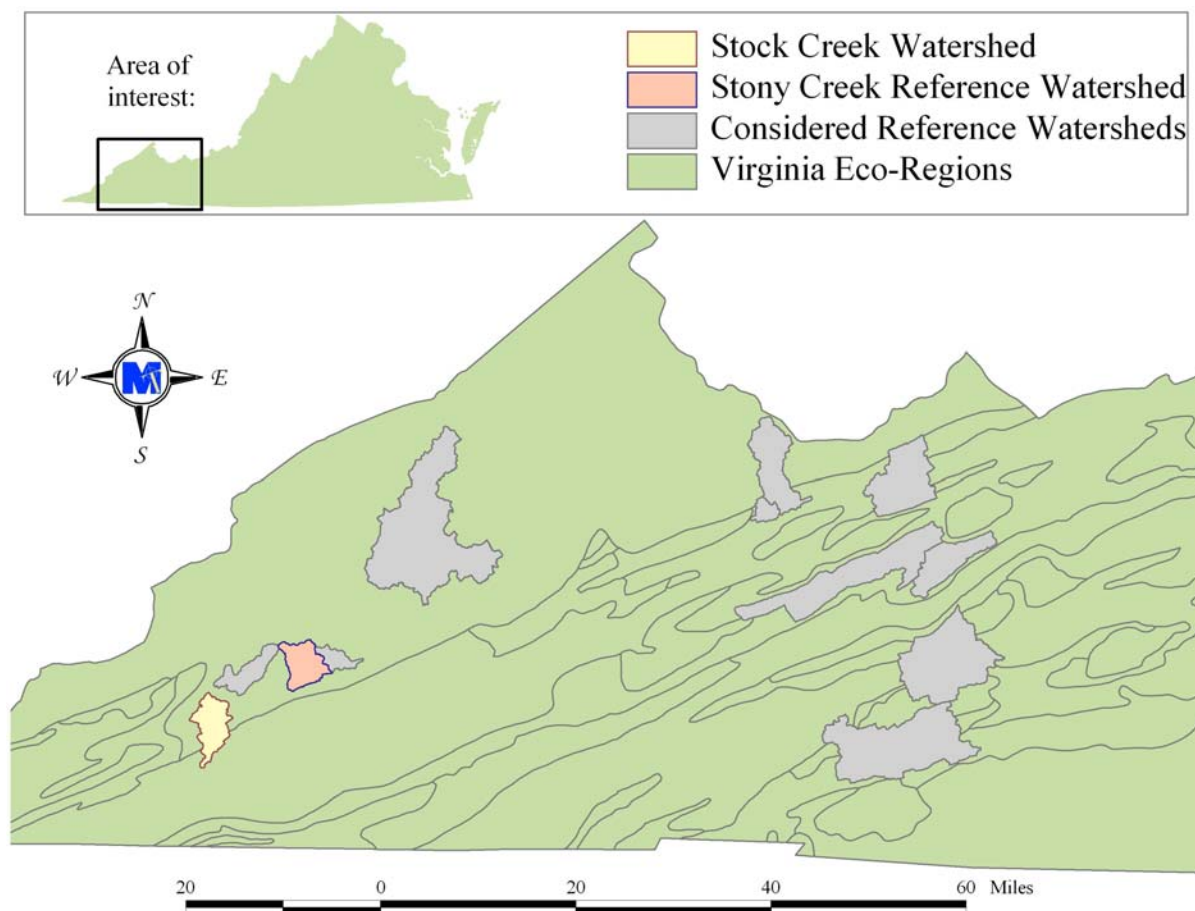
**Figure 3.15     Location of selected and potential reference watersheds**.

**Table 3.4     Reference watershed selection for Stock Creek – Part 1.**

| Stream | Stock Creek | Stony Creek | Little Stony Creek | South Fork Powell River | Indian Creek | Laurel Creek | McClure River |
|---|---|---|---|---|---|---|---|
| **General** | | | | | | | |
| Basin | Tnn_BS | Tnn_BS | Tnn_BS | Tnn_BS | Tnn_BS | Tnn_BS | Tnn_BS |
| HUC | 06010205 | 06010205 | 06010205 | 06010206 | 06010206 | 06010101 | 05070202 |
| Area (acres) | 11,081 | 10,360 | 4,094 | 8,420 | 18,288 | 37,010 | 68,039 |
| Stream Order | 3 | 4 | 3 | 3 | 3 | 3 | 4 |
| **Land Use** | | | | | | | |
| Active Mining | | | | | 4.67 | | 465.68 |
| AML/Bare Rock, Sand & Clay | 22.28 | | | | | | |
| Barren | 0.22 | 3.34 | 1.11 | | 162.12 | 16 | 700.75 |
| Commercial | 0.22 | | 0.222 | 2.002 | 0.890 | 1.11 | 100.298 |
| Crops | 26 | 2.00 | | 0.22 | 223.28 | 404 | 380.95 |
| Forest | 10,840 | 10,337 | 4,036 | 8,015 | 16,648 | 33,630 | 64,369 |
| Pasture | 47 | 4 | 2 | 306 | 1,204 | 2,888 | 1,691 |
| Reclaimed | 1.00 | | | | | | |
| Residential | 10.55 | | | 1.33 | 18.90 | 2.45 | 89.40 |
| Water | 124.89 | 0.45 | 30.91 | 66.05 | 10.45 | 4.67 | 228.84 |
| Wetlands | 8.59 | 17.35 | 20.46 | 32.91 | 13.79 | 63.2 | 11.79 |
| Slope (degrees) | 17.44 | 18.24 | 14.68 | 16.49 | 16.93 | 18.07 | 22.87 |
| Aspect (degrees) | 161.27 | 178.37 | 170.44 | 188.89 | 182.17 | 184.31 | 181.76 |
| **Soil Type** | | | | | | | |
| TN134_MUID | | | | | | 22.05 | |
| TN151_MUID | | | | 4.44 | 16.92 | | |
| TN164_MUID | | | | | | 13.47 | |
| VA001_MUID | | | | | | 60.07 | 10.62 |
| VA001_MUID | | | | | | 3.976 | |
| VA016_MUID | | | | | | 0.424 | |
| VA047_MUID | 9.57 | | | | | | |
| VA054_MUID | | | | | 7.01 | | |
| VA055_MUID | | | | | 71.47 | | |
| VA056_MUID | | 100 | 100 | 95.56 | 4.59 | | 89.38 |
| VA078_MUID | 90.43 | | | | | | |

**Table 3.4     Reference watershed selection for Stock Creek – Part 1 (cont.)**

| Stream | Stock Creek | Stony Creek | Little Stony Creek | South Fork Powell River | Indian Creek | Laurel Creek | McClure River |
|---|---|---|---|---|---|---|---|
| **Soil Properties** | | | | | | | |
| Hydrologic Group (avg): | 2.65 | 2.7 | 2.7 | 2.68 | 2.57 | 2.6 | 2.69 |
| Weighted Erodibility  Kffactor | 0.223 | 0.218 | 0.218 | 0.22 | 0.267 | 0.213 | 0.215 |
| Available Water Capacity | 0.091 | 0.088 | 0.088 | 0.09 | 0.11 | 0.090 | 0.087 |
| Unsaturated SMC | 0.819 | 0.746 | 0.746 | 0.778 | 0.99 | 0.86 | 0.738 |
| **Sub-ecoregion** | | | | | | | |
| Cumberland Mountains | 77.67 | 100 | 100 | 100 | 78.37 | | 100 |
| Southern Igneous Ridges and Mountains | | | | | 21.63 | | |
| Southern Dissected Ridges and Knobs | | | | | | 0.533 | |
| Southern Limestone/Dolomite Valleys and Low Rolling Hills | 22.33 | | | | | 99.47 | |

*Stock Creek, VA*

**Table 3.5     Reference watershed selection for Stock Creek - Part 2.**

| Stream | Stock Creek | Clinch River | Indian Creek | Middle Fork Holston River | South Fork Holston River | Lick Creek |
|---|---|---|---|---|---|---|
| **General** | | | | | | |
| Basin | Tnn_BS | Tnn_BS | Tnn_BS | Tnn_BS | Tnn_BS | Tnn_BS |
| HUC | 06010205 | 06010206 | 06010206 | 06010102 | 06010102 | 06010101 |
| Area (acres) | 11,081 | 22,943 | 21,384 | 37,809 | 48,162 | 14773 |
| Stream Order | 3 | 3 | 3 | 3 | 3 | 3 |
| **Land Use** | | | | | | |
| Active Mining | | | 4.67 | 11.56 | 0.22 | |
| AML/Bare Rock, Sand & Clay | 22.28 | 316.24 | | 591.335 | 163.234 | |
| Barren | 0.22 | 34 | 162.57 | 91.85 | 24.02 | 32.02 |
| Commercial | 0.22 | 316.24 | 0.890 | 591.335 | 163.234 | |
| Crops | 26 | 614.24 | 406.53 | 390.52 | 247.52 | 95.41 |
| Forest | 10,840 | 11,729 | 19,081 | 27,388 | 40,237 | 14,434 |
| Pasture | 47 | 9,594 | 1,649 | 8,695 | 6,804 | 188.36 |
| Reclaimed | 1.00 | | | | | |
| Residential | 10.55 | 596 | 54.04 | 600.68 | 663.84 | |
| Water | 124.89 | 38.25 | 13.79 | 8.01 | 4.89 | 6.01 |
| Wetlands | 8.59 | 23 | 14.01 | 32.69 | 20 | 14.9 |
| Slope (degrees): | 17.44 | 14.28 | 17.08 | 14.78 | 15.66 | 20.18 |
| Aspect (degrees) | 161.27 | 201.25 | 183.6 | 192.69 | 196.79 | 186.85 |
| **Soil Type** | | | | | | |
| TN134_MUID | | 3.86 | | 26.05 | 32.74 | 84.24 |
| TN138_MUID | | | | | | |
| TN151_MUID | | 63.44 | 24.07 | 29.96 | 11.87 | |
| TN164_MUID | | | 0.648 | | 6.97 | 3.30 |
| VA001_MUID | | 1.86 | | 10.92 | 6.57 | 12.46 |
| VA004_MUID | | | | 22.75 | 24.29 | |
| VA005_MUID | | | | 10.33 | 4.32 | |
| VA006_MUID | | | | | 13.25 | |
| VA016_MUID | | 27.26 | | | | |
| VA047_MUID | 9.57 | | | | | |
| VA054_MUID | | 3.59 | 5.98 | | | |
| VA055_MUID | | | 65.39 | | | |
| VA056_MUID | | | 3.91 | | | |
| VA078_MUID | 90.43 | | | | | |

**Table 3.5    Reference watershed selection for Stock Creek - Part 2 (cont.)**

| Stream | Stock Creek | Clinch River | Indian Creek | Middle Fork Holston River | South Fork Holston River | Lick Creek |
|---|---|---|---|---|---|---|
| **Soil Properties** | | | | | | |
| Hydrologic Group (avg): | 2.65 | 2.35 | 2.53 | 2.7 | 2.46 | 2.80 |
| Weighted Erodibility Kffactor | 0.223 | 0.25 | 0.267 | 0.233 | 0.233 | 0.22 |
| Available Water Capacity | 0.091 | 0.12 | 0.109 | 0.093 | 0.10 | 0.07 |
| Unsaturated SMC | 0.819 | 1.31 | 1.03 | 1.17 | 1.22 | 0.94 |
| **Ecoregion** | | | | | | |
| Cumberland Mountains | 77.67 | 3.39 | 68.22 | | | |
| Southern Dissected Ridges and Knobs | | | | 23.51 | | |
| Southern Igneous Ridges and Mountains | | 70.36 | 31.78 | 30.25 | 20.63 | |
| Southern Limestone/Dolomite Valleys and Low Rolling Hills | 22.33 | 26.25 | | 6.36 | | 100 |
| Southern Sandstone Ridges | | | | 19.7 | 71.83 | |
| Southern Sedimentary Ridges | | | | 20.17 | 7.51 | |

# 4. MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between in-stream water quality and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. In the development of a TMDL for the Stock Creek watershed, the relationship was defined through computer modeling based on data collected throughout the watershed. Monitored flow and water quality data were then used to verify that the relationships developed through modeling were accurate. In this section, the selection of modeling tools, parameter development, calibration, and model application for sediment are discussed.

## 4.1 Modeling Framework Selection

### 4.1.1 GWLF - Sediment

A reference watershed approach was used in this study to develop a benthic TMDL for sediment for the Stock Creek watershed. As noted in Chapter 3, sediment was identified as a probable stressor for Stock Creek. A watershed model was used to simulate sediment loads from potential sources in Stock Creek and the Stony Creek reference watershed. The model used in this study was the *Visual Basic^TM* version of the Generalized Watershed Loading Functions (GWLF) model with modifications for use with ArcView (Evans et al., 2001). The model also included modifications made by Yagow et al., 2002 and BSE, 2003. Numeric endpoints were based on unit-area loading rates calculated for the respective reference watershed. The TMDL was then developed for the impaired watershed based on these endpoints and the results from load allocation scenarios.

The GWLF model was developed at Cornell University (Haith and Shoemaker, 1987; Haith, et al., 1992) for use in ungaged watersheds. It was chosen for this study as the model framework for simulating sediment. GWLF is a continuous simulation spatially-lumped model that operates on a daily time step for water balance calculations and monthly calculations for sediment and nutrients from daily water balance. In addition to runoff and sediment, the model can simulate dissolved and attached nitrogen and phosphorus loads delivered to streams from watersheds with both point and nonpoint sources of pollution. The

model considers flow input from both surface and groundwater.  Land use classes are used as the basic unit for representing variable source areas.  The calculation of nutrient loads from septic systems, streambank erosion from livestock access, and the inclusion of sediment and nutrient loads from point sources are also supported.  Runoff is simulated based on the Soil Conservation Service's Curve Number Method (SCS, 1986).  Erosion is calculated from a modification of the Universal Soil Loss Equation (USLE) (Schwab et al., 1983; Wischmeier and Smith, 1978).  Sediment estimates use a delivery ratio based on a function of watershed area and erosion estimates from the modified USLE.  The sediment transported depends on the transport capacity of the runoff.

For execution, GWLF uses three input files for weather, transport, and nutrient loads.  The weather file contains daily temperature and precipitation for the period of record. The transport file contains input data related to hydrology and sediment transport.  The nutrient file contains primarily nutrient values for the various land uses, point sources, and septic system types, but does include urban sediment buildup rates.

### 4.2   Model Setup

The National Land Cover Data (NLCD) produced cooperatively between USGS and EPA was utilized for this study.  The collaborative effort to produce this dataset is part of a Multi-Resolution Land Characteristics (MRLC) Consortium project led by four U.S. government agencies: EPA, United States Geological Survey (USGS), the Department of the Interior National Biological Service (NBS), and the National Oceanic and Atmospheric Administration (NOAA).

Using 30-meter resolution Landsat 5 Thematic Mapper (TM) satellite images taken between 1990 and 1994, digital land use coverage was developed identifying up to 21 possible land use types.  Classification, interpretation, and verification of the land cover dataset involved several data sources (when available) including: aerial photography; soils data; population and housing density data; state or regional land cover data sets; USGS land use and land cover (LUDA) data; 3-arc-second Digital Terrain Elevation Data (DTED) and derived slope, aspect and shaded relief; and National Wetlands Inventory (NWI) data.

The land area of the Stock Creek watershed is approximately 11,080 acres, with forest accounting for the majority of the watershed (Table 4.1 and Figure 4.1). This land area applies to the portion of the watershed upstream of the impaired segment, which ends at VADEQ monitoring station 6BSTO004.73 approximately one mile downstream from the Bishop Creek confluence. Only the portion of the watershed including and upstream of the impaired segement was considered in the modeling and subsequent allocations. Approximate proportions of specific land uses are 98% forest, 1% water, with residential, abandoned mine land, agriculture, and quarries accounting for the remaining 1%.

**Table 4.1        Land use and area of Stock Creek watershed.**

| Land use | Acreage |
|---|---|
| Forest | 10,787.90 |
| Water | 118.72 |
| Residential | 33.05 |
| Agricultural | 70.13 |
| Limestone quarries | 22.51 |
| Abandoned Mining | 47.72 |
| **Total** | **11,080.03** |
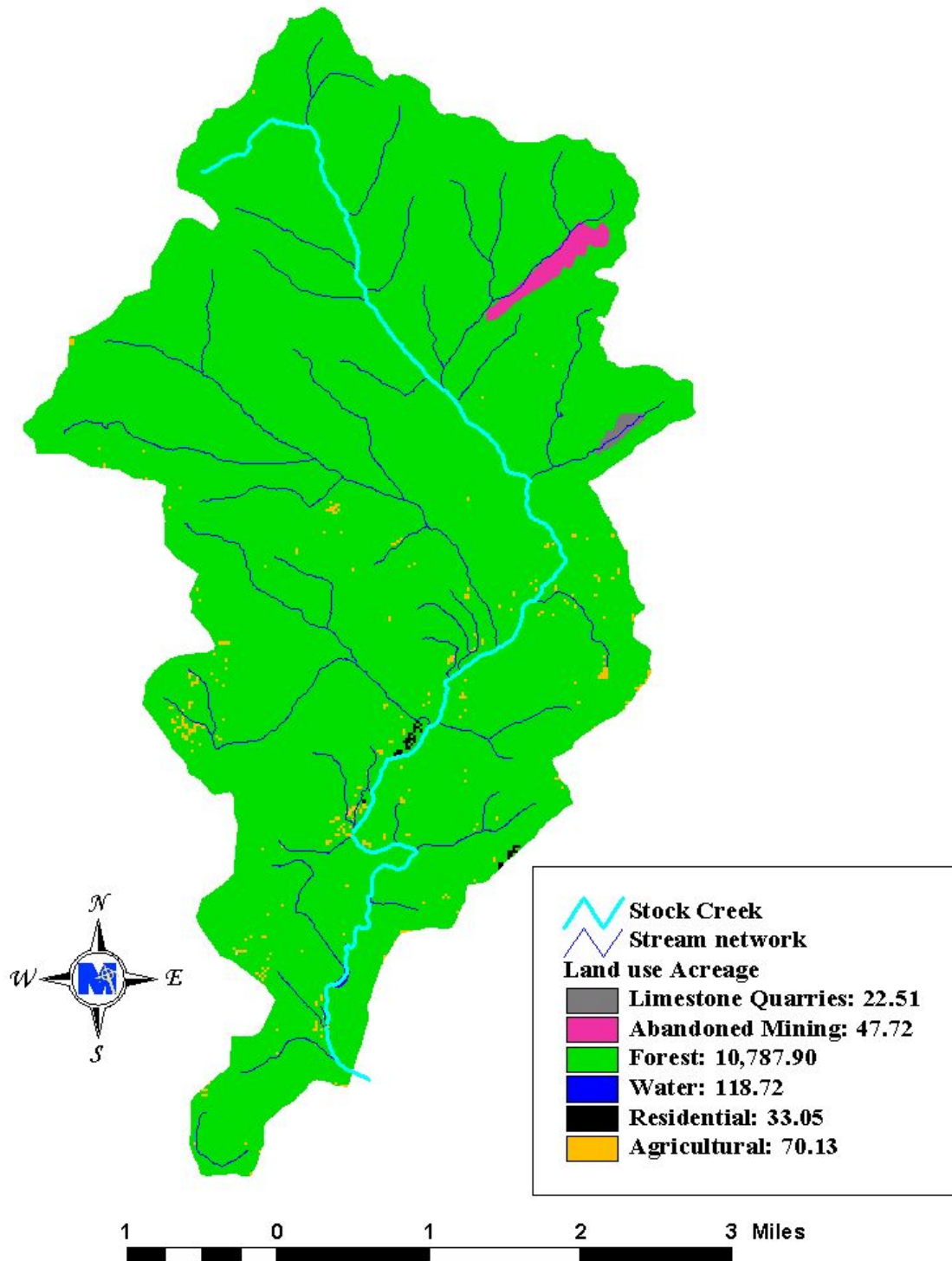
**Figure 4.1     Land uses in the Stock Creek Watershed.**

Using aerial photographs, MRLC, U.S. Census Bureau Topologically Integrated Geographic
Encoding and Referencing (TIGER), along with DMME maps, VDOT street maps, Jefferson

Forest road maps, and Digital Ortho Quarter Quads (DOQQs), possible land use types in the watershed were identified.  The land use types were consolidated into 12 categories based on similarities in hydrologic features (Table 4.2).

**Table 4.2      Land use categories for the Stock Creek watershed.**

| TMDL Land use Categories | Pervious / Impervious (Percentage) | Land use Classifications (MRLC Class No. where applicable) |
|---|---|---|
| Abandoned Mined Land | Pervious (100%) | Abandoned mine land |
| Reclaimed Mining | Pervious (100%) | Land regraded and revegetated after mining operations |
| Limestone Quarries | Pervious (90%) Impervious (10%) | Transitional (33) Delineated based on DOQQs |
| Residential | Pervious (90%) Impervious (10%) | Low Intensity Residential (21) |
| Forest | Pervious (100%) | Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43) |
| Pasture | Pervious (100%) | Pasture/Hay (81) |
| Secondary Roads | Impervious (100%) | Asphalt paved roads |
| Forest Roads | Impervious (100%) | Gravel and dirt roads |
| Row Crops | Pervious (100%) | Row Crops (82) |
| Water | Pervious (100%) | Open Water (11) |
| Wetlands | Pervious (100%) | Woody Wetlands (91) Emergent Herbaceous Wetland (92) |
| Disturbed Forest | Pervious (100%) | Delineated based on DOQQs |

## 4.2.1  GWLF - Sediment

Watershed data needed to run GWLF used in this study were generated using Geographical Information System (GIS) spatial coverage, local weather data, streamflow data, literature

values, and other data. Watershed boundaries for the impaired stream segment and the selected reference watershed were delineated from USGS 7.5 minute digital topographic maps using GIS techniques. The outlet for reference watershed Stony Creek was located at biological monitoring station 6BSNY005.68, upstream of the confluence with Coalpit Branch. For TMDL development, the total area for the Stony Creek reference watershed was equated with the area of the Stock Creek watershed. To accomplish this, the area of land use categories in the Stony Creek reference watershed was proportionally increased based on the percentage of land use distribution. As a result, the watershed area for Stony Creek was increased to be equal to the watershed area for the Stock Creek watershed. After adjustment, the distribution of land use remained the same as pre-adjustment values.

The GWLF model was developed to simulate runoff, sediment and nutrients in ungaged watersheds based on landscape conditions such as land use/landcover, topography, and soils. In essence, the model uses a form of the hydrologic units (HU) concept to estimate runoff and sediment from different pervious areas (HUs) in the watershed (Li, 1972; England, 1970). In the GWLF model, the nonpoint source load calculation for sediment is affected by land use activity (*e.g.,* farming practices), topographic parameters, soil characteristics, soil cover conditions, stream channel conditions, livestock access, and weather. The model utilizes land use categories as the mechanism for defining homogeneity of source areas. This is a variation of the HU concept, where homogeneity in hydrologic response or nonpoint source pollutant response would typically involve the identification of soil land use topographic conditions that would be expected to give a homogeneous response to a given rainfall input. A number of parameters are included in the model to index the effect of varying soil-topographic conditions by land use entities. A description of model parameters is given in Section 4.2.1.1 followed by a description of how parameters and other data were calculated and/or assembled.

### 4.2.1.1 Description of Model Input Parameters

The following description of GWLF model input parameters was taken from *Benthic TMDL for Stroubles Creek in Montgomery County, Virginia* (BSE, 2003).

**Hydrologic Parameters**

*Watershed-Related Parameter Descriptions*

- *Unsaturated Soil Moisture Capacity (SMC): The amount of moisture in the root zone, evaluated as a function of the area-weighted soil type attribute – available water capacity.*

- *Recession Coefficient (/day): The recession coefficient is a measure of the rate at which streamflow recedes following the cessation of a storm, and is approximated by averaging the ratios of streamflow on any given day to that on the following day during a wide range of weather conditions, all during the recession limb of each storm's hydrograph.*

- *Seepage Coefficient (/day): The seepage coefficient represents the amount of flow lost as seepage to deep storage.*

Running the model for a 12-month period prior to the chosen period during which loads were calculated, initialized the following parameters.

- *Initial unsaturated storage (cm): Initial depth of water stored in the unsaturated (surface) zone.*

- *Initial saturated storage (cm): Initial depth of water stored in the saturated zone.*

- *Initial snow (cm): Initial amount of snow on the ground at the beginning of the simulation.*

- *Antecedent Rainfall for each of 5 previous days (cm): The amount of rainfall on each of the five days preceding the first day in the weather file.*

*Month-Related Parameter Descriptions*

- *Month: Months were ordered, starting with April and ending with March – in keeping with the design of the GWLF model and its assumption that stored sediment is flushed from the system at the end of each Apr-Mar cycle. Model output was modified in order to summarize loads on a calendar-year basis.*

- *ET_CV: Composite evapo-transpiration cover coefficient, calculated as an area-weighted average from land uses within each watershed.*

- *Hours per Day: Mean number of daylight hours.*

- *Erosion Coefficient: This a regional coefficient used in Richardson's equation for calculating daily erosivity. Each region is assigned separate coefficients for the months October-March, and for April-September.*

## *Land Use-Related Parameter Descriptions*

- *Curve Number: The SCS curve number (CN) is used in calculating runoff associated with a daily rainfall event, evaluated using SCS TR-55 guidance.*

## *Sediment Parameters*

### *Watershed-Related Parameter Descriptions*

- *Sediment delivery ratio: The fraction of erosion – detached sediment – that is transported or delivered to the edge of the stream, calculated as an inverse function of watershed size (Evans et al., 2001).*

### *Land Use-Related Parameter Descriptions*

- *USLE K-factor: The soil erodibility factor was calculated as an area-weighted average of all component soil types.*

- *USLE LS-factor: This factor is calculated from slope and slope length measurements by land use. Slope is evaluated by GIS analysis, and slope length is calculated as an inverse function of slope.*

- *USLE C-factor: The vegetative cover factor for each landuse was evaluated following GWLF manual guidance and Wischmeier and Smith (1978), and Hession et al.*

- *Daily sediment buildup rate on impervious surfaces: The daily amount of dry deposition deposited from the air on impervious surfaces on days without rainfall, assigned using GWLF manual guidance.*

*Streambank Erosion Parameter Descriptions (Evans, 2002)*

- *% Developed land: percentage of the watershed with urban-related land uses - defined as all land...*

- *Animal density: calculated as the number of beef and dairy 1000-lb equivalent animal units (AU) divided by watershed area in acres.*

- *Stream length: calculated as the total stream length of natural stream channel, in meters. Excludes the non-erosive hardened and piped sections of the stream.*

- *Stream length with livestock access: calculated as the total stream length in the watershed where livestock have unrestricted access to streams, resulting in streambank trampling in meters.*

### 4.2.1.2  Streamflow and Weather Data

The GWLF model was calibrated for hydrology using observed flow data for Stony Creek. The station used was USGS station number 03524900.  Daily precipitation and temperature data were obtained from NCDC weather stations in Virginia (Table 4.3).

**Table 4.3      Weather stations used in GWLF models for Stock Creek and Stony Creek.**

| Watersheds | Weather Stations (station_id, location, Thiessen weights) | Data Type | Period of Record |
|---|---|---|---|
| Stock Creek | Station ID:  440735 Location: Grundy, VA Thiessen weight: 1 | Daily Precipitation & Temperature | 1/1/1979–current |
| Stony Creek | Station ID:  440735 Location: Richlands,VA Thiessen weight: 1 | Daily Precipitation & Temperature | 7/1/1979–current |

### 4.2.1.3  Land use/landcover classes

Land use classes are used as the basic response unit for performing runoff and erosion calculations and summarizing sediment transport.  Land use maps were obtained from MRLC data (USEPA, 1992) for the impaired and reference watersheds.  The land use categories were consolidated from MRLC classifications as given in Table 4.2.  Urban land use categories (residential) were further subdivided into a pervious (PER) and an impervious

(IMP) component. The percentage of impervious and pervious area was assigned from data provided in VADCR's online 2004 NPS Assessment Database (VADCR, 2004). The pasture/hay category was subdivided into three sub-categories: hay, overgrazed pasture, and unimproved pasture. The percentage of the pasture/hay acreage that was assigned to each category was based on field observations and VADCR's online 2004 NPS assessment database. Cropland was also sub-divided into two sub-categories: low tillage and high tillage. The percentage assigned to each cropland sub-category was obtained from VADCR's online database and Gall, 2004. The permitted mining and abandoned mined land categories were obtained from DMME and delineated based on aerial photos. Land use distributions for Stock Creek and Stony Creek are given in Table 4.4. Land use areas for Stony Creek were adjusted by the ratio of impaired watershed to reference watershed while maintaining the original land use distribution.

The weighted C-factor for each land use category was estimated following guidelines given in Wischmeier and Smith, 1978, GWLF User's Manual (Haith et al., 1992), and Kleene, 1995.

**Table 4.4      Land use distributions for Stock Creek and reference watershed Stony Creek.**

| Land use Category | Stock Creek (ha*) | Stony Creek (adjusted) (ha) |
|---|---|---|
| Forest-disturbed (for_dis) | 184.81 | 121.69 |
| Forest (for) | 4152.84 | 4232.18 |
| Pasture – Hay (pas1) | 3.66 | 0.31 |
| Pasture – Overgrazed (pas2) | 14.62 | 0.00 |
| Pasture – Unimproved (pas3) | 0.00 | 1.25 |
| Permitted Mining-reclaimed mine lands (pm_rel) | 0.40 | 0.00 |
| Abandoned mined land (aml) | 19.32 | 35.45 |
| Residential_per (res_per) | 2.07 | 0.00 |
| High_tillage (h_til) | 8.69 | 0.75 |
| Low_tillage (l_til) | 1.42 | 0.12 |
| Wetlands (wet) | 3.45 | 6.44 |
| Water (wt) | 48.05 | 44.28 |
| Residential_imp (res_imp) | 2.18 | 0.00 |
| Forest Roads (for_rd) | 24.37 | 37.95 |
| Secondary Roads (Sec_rd) | 9.20 | 4.94 |

* 1 hectare = 2.47 acres

## 4.2.1.4  Sediment Parameters

Sediment parameters include USLE parameters K, LS, C, and P, sediment delivery ratio, and buildup and loss function for impervious surfaces. The product of the USLE parameters, KLSCP, is entered as input to GWLF.  The K factor relates to a soil's inherent erodibility and affects the amount of soil erosion from a given field.  Soils data for Stock Creek and Stony Creek were obtained from the State Soil Geographic (STATSGO) database for Virginia (NRCS, 2004b) for Scott County.  The area-weighted K-factor by land use category was calculated using GIS procedures.  Land slope was calculated from USGS Digital Elevation Models (DEMs) using GIS techniques.  The length-of-slope was based on VirGIS procedures given in VirGIS Interim Reports (Shanholtz et al., 1988).  The VirGIS length-of-slope values were developed in cooperation with local SCS office personnel for much of Virginia.  The area-weighted slope and length-of-slope were calculated by land use category using GIS procedures.  The area-weighted LS factor was calculated for each land use category using procedures recommended by Wischmeier and Smith (1978).   The average soil solum thickness and corresponding available soil moisture capacity were obtained from soils data and used to estimate the unsaturated soil moisture capacity.

### 4.2.1.5  Pervious and Impervious Surfaces

Each urban area was sub-divided into pervious areas (USLE sediment algorithm applies) and impervious areas (where an exponential buildup-washoff algorithm applies). The percentage of pervious and impervious area was calculated from data obtained from VADCR's 2004 NPS Assessment Database (VADCR, 2004).

The daily sediment buildup rate on impervious surfaces (which represents the daily amount of dry deposition from the air on days without rainfall) was assigned using guidance from the GWLF manual (Haith et al. 1992).  For this study, the values assigned as the daily build-up rate were taken from the BSE, 2003 study.

### 4.2.1.6  Sediment Delivery Ratio

The sediment delivery ratio specifies the percentage of eroded sediment delivered to surface water and is empirically based on watershed size.  The sediment delivery ratios for impaired and reference watersheds were calculated as an inverse function of watershed size (Evans et al., 2001).

### 4.2.1.7  SCS Runoff Curve Number

The runoff curve number is a function of soil type, antecedent moisture conditions, and cover and management practices. The runoff potential of a specific soil type is indexed by the Soil Hydrologic Group (HG) code.  Each soil-mapping unit is assigned HG codes that range in increasing runoff potential from A to D. The soil HG code was given a numerical value of 1 to 4 to index HG codes A to D, respectively.  An area-weighted average HG code was calculated for each land use/land cover from soil survey data using GIS techniques. Runoff curve numbers (CN) for soil HG codes A to D were assigned to each land use/land cover condition for antecedent moisture condition II following GWLF guidance documents and SCS, 1986 recommended procedures.  The runoff CN for each land use/land cover condition was then adjusted based on the numerical area-weighted soil HG codes.

### 4.2.1.8  Parameters for Channel and Streambank Erosion

Parameters for streambank erosion include animal density, total length of streams, total length of natural stream channel, percent-developed land, mean stream depth, watershed soil

erodibility, watershed average slope, land use, and watershed area. Based on site visits and correspondence with local stakeholders, it was assumed that there is negligible livestock effect on streambank erosion in both the impaired and the reference watersheds. Stream length, watershed land use, slope, and soils were all obtained from GIS maps of the watersheds.

### 4.2.1.9  Evapotranspiration Cover Coefficients

Evapotranspiration (ET) cover coefficients are entered by month. Monthly ET cover coefficients were assigned each land use/land cover condition (from MRLC classification) following procedures outlined in Novotny and Chesters (1981) and GWLF guidance. Area-weighted ET cover coefficients were then calculated for each sediment source class.

## 4.3  Source Representation

### 4.3.1  GWLF - Sediment

The source area identified as the primary contributor to sediment loading in the Stock Creek watershed involves surface runoff. The sediment process is a continual process but is often accelerated by human activity. An objective of the TMDL process is to minimize the acceleration process. This section describes predominant sediment source areas, model parameters, and input data needed to simulate sediment loads.

### 4.3.1.1  Surface Runoff

During runoff events (natural rainfall or irrigation), sediment is transported to streams from pervious land areas (*e.g.,* forest, agricultural fields, lawns, etc.). Rainfall intensity, soil cover, soil characteristics, topography, and land management affect the magnitude of sediment loading. Agricultural management activities such as overgrazing (particularly on steep slopes), high tillage operations, mining operations, forest harvesting, and construction (roads, buildings, etc.) all tend to accelerate erosion at varying degrees. During dry periods, sediment from air or traffic builds up on impervious areas and is transported to streams during runoff events. The magnitude of sediment loading from this source is affected by various factors (*e.g.,* the deposition from wind erosion and vehicular traffic).

### 4.3.1.2  Point Sources

One VPDES point source was identified in the Stock Creek watershed with discharge specifics listed in Table 4.5. Permitted load was calculated as the maximum annual modeled runoff times a maximum TSS concentration. No permitted point sources exist in Stony Creek watershed. The point source in Stock Creek existed at the time of calibration.

**Table 4.5          VPDES point source facilities and permitted TSS load.**

| Stock Creek Point Sources | | Existing Conditions | | |
|---|---|---|---|---|
| **VPDES ID** | **Name** | **Permit Discharge (MGD)** | **Conc. (mg/L)** | **TSS (Mg/yr)** |
| **Industrial Stormwater Discharge Permits** | | | | |
| VA0052655 | Chemetall Foote Corporation - Sunbright | 0.2 | 30 | 8.1 |
| | **Total Point Source Loads** | | | 8.1 |

## 4.4    Stream Characteristics

### 4.4.1   GWLF - Sediment

The GWLF model does not support in-stream flow routing. An empirical relationship developed by Evans et al., 2001 and modified by BSE, 2003 requires total watershed stream length of the natural channel and the average mean depth for making estimates of channel erosion. This calculation excludes the non-erosive hardened and piped sections of a stream.

## 4.5    Selection of Representative Modeling Period

Selection of the modeling period was based on three factors: availability of data (discharge and water quality), the degree of land-disturbing activity, and the need to represent critical hydrological conditions. Modeling periods were selected for hydrology calibration and modeling of allocation scenarios. Flow data were available only for Stony Creek watershed and for a limited time period from 03/1980 though 09/1981 (Section 2.5.1). Due to the limited availability of stream flow data, the entire period was used for calibrating the hydrologic component of the model rather than dividing the dataset into smaller components for calibration and validation. The modeling period was set for four years between 04/1997 and 03/2001. This period was selected due to the stability of land use. The hydrologic landscape of the watershed was relatively stable during the modeled period.

### 4.6   Sensitivity Analysis

Sensitivity analyses were conducted to assess the sensitivity of the model to changes in hydrologic and water quality parameters as well as to assess the impact of unknown variability in source allocation (*e.g.*, seasonal and spatial variability of crop cover conditions, runoff curve number, etc.).  Sensitivity analyses were run on the runoff curve number (CN) and the combined erosion factor (KLSCP), which combines the effects of soil erodibility, land slope, land cover, and management practices (Table 4.6).  For a given simulation, the model parameters in Table 4.6 were set at the base value except for the parameter being evaluated.  The parameters were adjusted to -10% and 10% of the base value.  Results are listed in Table 4.7.  The results show that while CN changes have a large impact on runoff and sediment load, the KLSCP factor only impacts sediment load.  The results tend to reiterate the need to carefully evaluate conditions in the watershed and follow a systematic protocol in establishing values for model parameters.

**Table 4.6      Base watershed parameter values used to determine hydrologic and sediment response for Stock Creek.**

| Land use | Base Value | |
|---|---|---|
| | **CN** | **KLSCP** |
| Forest Roads | 87.8 | 0.283922 |
| Secondary Roads | 90.7 | 0.038272 |
| Forest – Disturbed | 77.5 | 0.471327 |
| Forest | 65.5 | 0.000548 |
| Pasture – Hay | 70.9 | 0.014834 |
| Pasture – Overgrazed | 83.5 | 0.556263 |
| Reclaimed mining | 67.1 | 0.024267 |
| Abandoned mining | 72.3 | 0.055626 |
| Limestone Quarries | 75.1 | 0.357744 |
| Pervious residential | 68.1 | 0.029417 |
| Impervious residential | 98.0 | --- |
| High tillage | 81.2 | 1.017308 |
| Low tillage | 78.5 | 0.447962 |
| Wetlands | 100 | 0 |
| Water | 100 | 0 |

**Table 4.7      Sensitivity of model response to changes in selected parameters.**

| Model Parameter | %Parameter Change | % Change in Runoff | % Change in Sediment Load |
|---|---|---|---|
| CN | -10 | -40.58 | -18.43 |
| CN | 10 | 101.00 | 5.788 |
| KLSCP | -10 | Insensitive | -9.922 |
| KLSCP | 10 | Insensitive | 9.922 |

## 4.7  Model Calibration Processes

Although the GWLF model was originally developed for use in ungaged watersheds, calibration was performed to ensure that hydrology was being simulated accurately. This process was necessary to minimize errors in sediment simulations due to potential gross errors in hydrology. The model's parameters were assigned based on available soils, land use, and topographic data. Parameters that were adjusted during calibration included the recession constant, the evapotranspiration cover coefficients, the unsaturated soil moisture storage, and the seepage coefficient.

Streamflow in Stock Creek is not continuously monitored; therefore, the hydrology component of the model was calibrated based on observed daily stream flow data for Stony Creek. The available record of daily flow for Stony Creek was between March 1, 1980 and September 30, 1981. Precipitation and temperature data were obtained from NCDC station 440735.

Model calibrations were considered very good for total runoff volume. Monthly fluctuations were variable but were still reasonably good considering the general simplicity of GWLF. Results were also consistent with other applications of GWLF in Virginia (*e.g.,* Tetra Tech, 2001 and BSE, 2003). The final calibration results for Stony Creek are given in Figures 4.2 and 4.3 with accuracy of fit statistics given in Table 4.8.
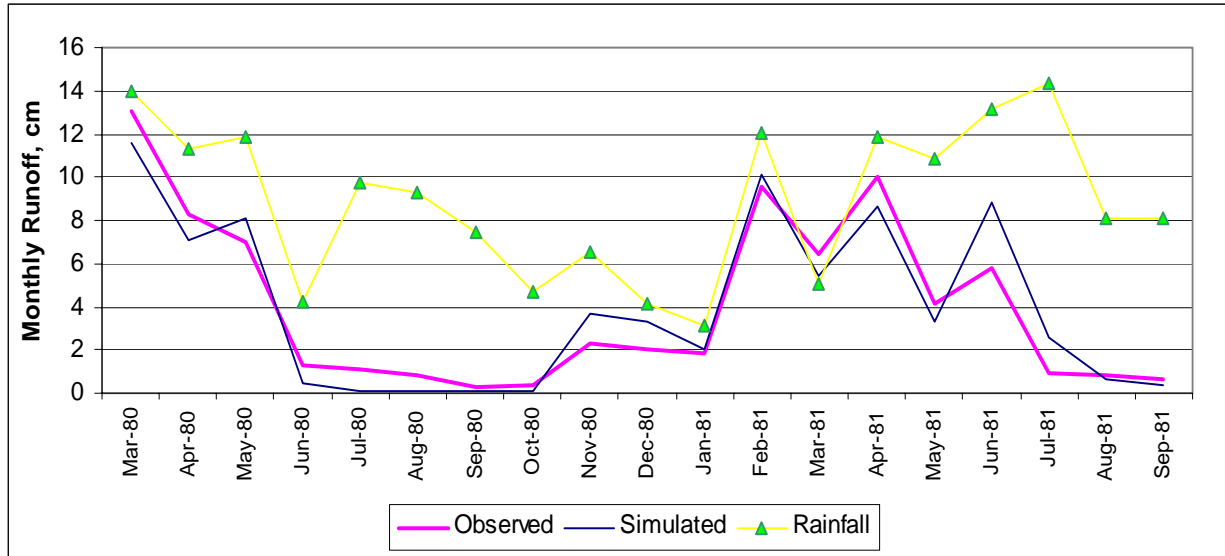
**Figure 4.2** **Comparison of monthly simulated and observed flow for Stony Creek watershed.**
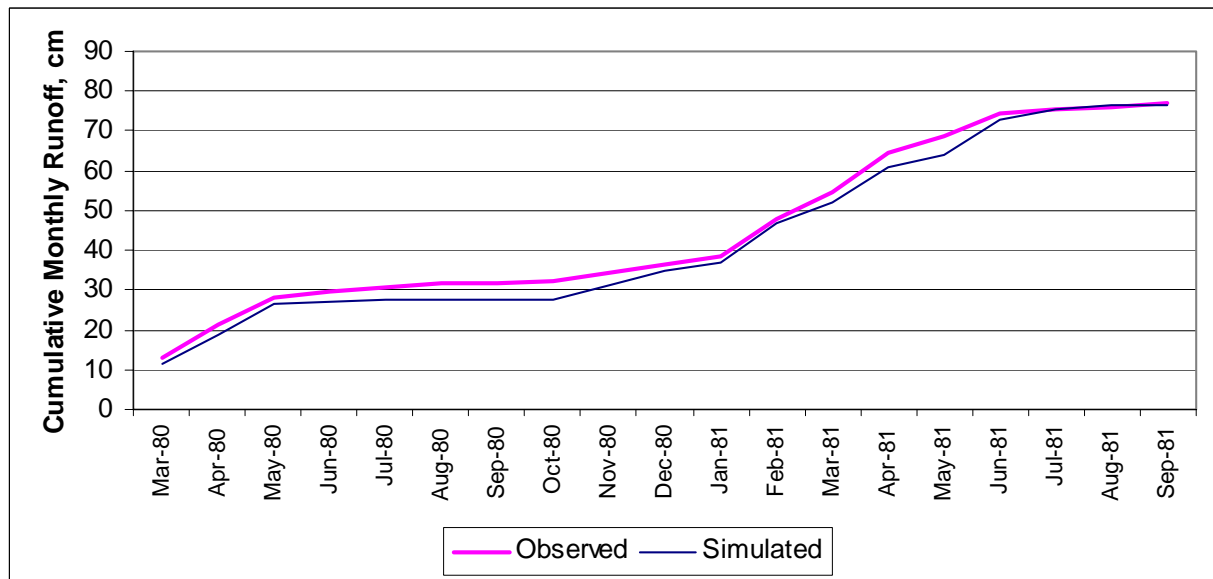


**Figure 4.3** **Comparison of cumulative monthly simulated and observed flow for Stony Creek watershed.**

**Table 4.8       GWLF flow calibration statistics.**

| Watersheds | Simulation Period | $R^2$ ($R^2$ Correlation value) | Total Volume Error (Sim-Obs) |
|---|---|---|---|
| Stony Creek | 3/1/80 – 9/30/1981 | 0.951 | 0.00 |

## 4.8  Existing Conditions

A listing of parameters from the GWLF Transport input files that were finalized during
hydrologic calibration for conditions existing at the time of impairment are given in Tables
4.9 – 4.12.  Watershed parameters for Stock Creek and reference watershed Stony Creek are
given in Table 4.9.  Monthly evaporation cover coefficients are listed in Table 4.10.

**Table 4.9       Stock Creek and reference watershed Stony Creek GWLF watershed
                        parameters for existing conditions.**

| GWLF Watershed Parameter | Units | Stock Creek | Stony Creek |
|---|---|---|---|
| Recession Coefficient | Day$^{-1}$ | 0.2 | 0.2 |
| Seepage Coefficient | Day$^{-1}$ | 0.0225 | 0.0225 |
| Sediment Delivery Ratio | --- | 0.145 | 0.145 |
| Unsaturated Water Capacity | (cm) | 10 | 10 |
| Erosivity Coefficient (Apr-Sep) | --- | 0.28 | 0.28 |
| Erosivity Coefficient (Oct-Mar) | --- | 0.10 | 0.10 |
| % developed land | (%) | 0.06 | 0.00 |
| Livestock density | (AU/ac) | 0.0000 | 0.0000 |
| Area-weighted soil erodibility | --- | 0.257 | 0.253 |
| Area weighted runoff curve number | --- | 67.25 | 66.84 |
| Total stream length | (m) | 76,445 | 67,647 |
| Mean channel depth | (m) | 0.69 | 0.68 |

**Table 4.10     Stock Creek and reference watershed Stony Creek GWLF monthly
                        evaporation cover coefficients for existing conditions.**

| | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ET_CV | 0.3 | 0.8 | 1 | 1 | 1 | 0.8 | 0.8 | 0.5 | 0.3 | 0.3 | 0.3 | 0.3 |

Table 4.11 lists the area-weighted USLE erosion parameter and runoff curve number by land
use erosion source areas for Stock Creek and the reference watershed Stony Creek.  The area
adjustment for the reference watershed is listed in Table 4.12.

**Table 4.11    Stock Creek and reference watershed Stony Creek GWLF landuse parameters for existing conditions.**

| Landuse Category | Stock Creek | | Stony Creek | |
|---|---|---|---|---|
| | CN | KLSCP | CN | KLSCP |
| Forest Roads | 87.8 | 0.283922 | 89.5 | 0.243593 |
| Secondary Roads | 90.7 | 0.038272 | 91.1 | 0.057963 |
| Forest-disturbed | 77.5 | 0.471327 | 77.5 | 0.477914 |
| Forest | 65.5 | 0.000548 | 65.5 | 0.000546 |
| Pasture - Hay | 70.9 | 0.014834 | 67.1 | 0.022278 |
| Pasture - Overgrazed | 83.5 | 0.556263 | --- | --- |
| Pasture - Unimproved | --- | --- | 76.0 | 0.417708 |
| Permitted Mining-Reclaimed mine lands | 67.1 | 0.024267 | --- | --- |
| Abandoned mining | 72.3 | 0.050238 | 73.7 | 0.093763 |
| Limestone quarries | 75.1 | 0.357744 | --- | --- |
| Pervious residential | 68.1 | 0.029417 | --- | --- |
| High tillage | 81.2 | 1.0129417 | 81.5 | 1.92955 |
| Low tillage | 78.5 | 0.447962 | 78.9 | 0.849660 |
| Wetlands | 100.0 | 0 | 100.0 | 0 |
| Water | 100.0 | 0 | 100.0 | 0 |
| Impervious residential | 98.0 | --- | 98.0 | --- |

**Table 4.12    Area adjustments for Stock Creek reference watershed Stony Creek.**

| Land use Categories | Impaired | Reference Original | Reference (area-adjusted) |
|---|---|---|---|
| | Stock Creek | Stony Creek | Stony Creek (x1.07) |
| | (ha) | (ha) | (ha) |
| Forest Roads | 24.36 | 35.47 | 37.95 |
| Secondary Roads | 9.06 | 4.62 | 4.94 |
| Forest-disturbed | 184.41 | 112.78 | 120.68 |
| Forest | 4152.84 | 3954.68 | 4231.5 |
| Pasture - Hay | 3.65 | 0.29 | 0.31 |
| Pasture - Overgrazed | 14.62 | --- | --- |
| Pasture - Unimproved | --- | 1.17 | 1.25 |
| Permitted Mining-Reclaimed mine lands | 0.4 | --- | --- |
| Abandoned mining | 19.32 | 33.13 | 35.45 |
| Limestone quarries | 9.20 | --- | --- |
| Pervious residential | 2.07 | --- | --- |
| High tillage | 8.69 | 0.70 | 0.75 |
| Low tillage | 1.42 | 0.11 | 0.12 |
| Wetlands | 3.45 | 6.02 | 6.44 |
| Water | 48.04 | 41.38 | 44.28 |
| Impervious residential | 2.16 | --- | --- |

The sediment loads existing at the time of impairment were modeled for Stock Creek and the reference watershed Stony Creek (Table 4.13).  The existing condition for the Stock Creek

watershed is the combined sediment load, which compares to the target TMDL load under existing conditions for the area-adjusted reference watershed Stony Creek. The target sediment load for Stock Creek is the average annual load from the area-adjusted Stony Creek watershed under existing conditions (2,643.58 Mg/yr), minus the margin of safety (10% or 264.36 Mg/yr), which results in 2,379.22 Mg/yr (Table 4.13).

**Table 4.13    Existing sediment loads for Stock Creek and reference watershed Stony Creek.**

| Sediment Source | Stock Creek watershed Existing Conditions | | Reference Stony Creek watershed (Area Adjusted) | |
|---|---|---|---|---|
| | Mg/yr | Mg/ha/yr | Mg/yr | Mg/ha/yr |
| Forest Roads | 305.97 | 12.56 | 421.84 | 11.21 |
| Secondary Roads | 15.85 | 1.75 | 13.12 | 2.66 |
| Forest-disturbed | 2919.47 | 15.83 | 1953.45 | 16.19 |
| Forest | 49.97 | 0.01 | 50.73 | 0.01 |
| Pasture – Hay | 1.51 | 0.41 | 0.15 | 0.49 |
| Pasture – Overgrazed | 335.79 | 22.97 | --- | --- |
| Pasture – Unimproved | --- | --- | 15.83 | 12.67 |
| Abandoned mining | 27.56 | 1.96 | 97.69 | 2.76 |
| Limestone quarries | 98.57 | 10.72 | --- | --- |
| Pervious residential | 1.46 | 0.7 | --- | --- |
| High tillage | 342.76 | 39.43 | 56.36 | 75.65 |
| Low tillage | 21.86 | 15.45 | 3.62 | 29.91 |
| Impervious residential | 0.47 | 0.22 | --- | --- |
| | | | | |
| **NPS Loads** | 4121.24 | 0.93 | 2612.80 | 0.58 |
| **VA0052655** | 8.10 | --- | --- | --- |
| **Channel Erosion** | 36.33 | | 30.78 | |
| **Watershed Totals** | 4165.67 | | 2643.58 | |

## 5.  ALLOCATION

Total Maximum Daily Loads consist of waste load allocations (WLAs, point sources) and load allocations (LAs, nonpoint sources), including natural background levels.  Additionally, the TMDL must include a margin of safety (MOS) that either implicitly or explicitly accounts for uncertainties in the process.  The definition is typically denoted by the expression:

$$TMDL = WLAs + LAs + MOS$$

The TMDL becomes the amount of a pollutant that can be assimilated by the receiving water body and still achieve water quality standards.  For sediment, the TMDL is expressed in terms of annual load (Mg/yr).

This section describes the development of TMDLs for sediment for the Stock Creek using a reference watershed approach.  The model was run for existing conditions over the period of April 1997 to March 1999.  As described in chapter 4 of this document, Stony Creek in Scott County, VA was selected as the reference watershed.  The average annual sediment load from the Stony Creek reference watershed was used to define the TMDL loads for the Stock Creek watershed.

### 5.1  Incorporation of a Margin of Safety

In order to account for uncertainty in modeled output, an MOS was incorporated into the TMDL development process.  Individual errors in model inputs, such as data used for developing model parameters or data used for calibration, may affect the load allocations in a positive or a negative way.

An MOS can be incorporated implicitly in the model through the use of conservative estimates of model parameters, or explicitly as an additional load reduction requirement.  The latter method was used in this report.

## 5.2   Sediment TMDL

Allowable sediment loads for Stock Creek were developed with the Stony Creek watershed as the reference watershed.  The area of the Stony Creek watershed was increased by the ratio of the impaired watershed area to the reference watershed area (1.07:1).   After adjustment, the Stony Creek reference watershed area equaled the Stock Creek watershed area (4,483.6 ha).  Land use areas for the Stony Creek watershed were increased while maintaining the original land use distribution.

The target TMDL load for Stock Creek is the average annual load from the area-adjusted Stony Creek watershed under existing conditions (Table 5.1).  The sediment TMDL for Stock Creek includes three components – WLA, LA, and MOS.  The WLA was calculated as the sum of all permitted point source discharges.  A permitted point source with permit ID VA0052655 is no longer operating and, therefore, was not considered in the allocation.  The WLA of 0.22 Mg/yr pertains to a former DMME mining permit in the watershed.  The MOS was explicitly set to 10% to account for uncertainty in developing TMDLs.  The LA was calculated as the target TMDL load minus the WLA load minus the MOS.

**Table 5.1        TMDL Targets for Stock Creek Watershed.**

| Impairment | WLA (Mg/yr) | LA (Mg/yr) | MOS | TMDL (Mg/yr) |
|---|---|---|---|---|
| Stock Creek | 0.00 | 2,379.23 | 264.36 | 2,643.58 |

Review of the Scott County Comprehensive Plan (Scott County Planning Commission, 2000) indicates that land use is not expected to change significantly over the next 25 years.  The Stock Creek watershed is forested with little rural development and it is assumed that residential and commercial growth in the watershed will not have an impact on future sediment loads.  Therefore, the reductions required to meet the TMDL were based on the conditions existing at the time of impairment.  An overall reduction of about 43% will achieve the desired reduction in sediment load as indicated in Table 5.2.  The predominant sediment loads are from forestland.

**Table 5.2       Required reductions for the Stock Creek impairment.**

| Stock Creek Current Load (Mg/yr) | Target Load (Mg/yr) | Reductions Required | |
|---|---|---|---|
| | | (Mg/yr) | (% of current load) |
| 4,165.65 | 2,379.22 | 1,786.44 | 42.88 |

Two sediment allocation scenarios are presented in Table 5.3.  The first scenario requires about equal reductions of sediment input from main sources.  The second scenario, however, requires significant reductions from disturbed forest with no reductions required from other sources.  Scenario 1 is recommended here since it is distributing the reductions in sediment loads to a wide variety of sources which entails improving erosion control practices in all aspects of human-controlled erosion producing activities.  The reductions are expected to be achieved through installing riparian buffers, streambank stabilization measures, reclaiming disturbed forest, and abandoned mind areas.

**Table 5.3        TMDL allocation scenarios for the Stock Creek impairment.**

| | | Scenario 1 | | Scenario 2 | |
|---|---|---|---|---|---|
| **Sediment Source Categories** | **Existing Sediment Load** | **Load Reduction** | **Allocation Sediment Load** | **Load Reduction** | **Allocation Sediment Load** |
| | **(Mg/yr)** | **(%)** | **(Mg/yr)** | **(%)** | **(Mg/yr)** |
| Forest Roads | 305.97 | 44.0 | 171.34 | 0.0 | 305.97 |
| Secondary Roads | 15.85 | 0.0 | 15.85 | 0.0 | 15.85 |
| Forest - Disturbed | 2919.47 | 44.0 | 1634.90 | 61.0 | 1138.59 |
| Forest - Undisturbed | 49.97 | 0.0 | 49.97 | 0.0 | 49.97 |
| Pasture - Hay | 1.51 | 0.0 | 1.51 | 0.0 | 1.51 |
| Pasture - Overgrazed | 335.79 | 43.0 | 191.4 | 0.0 | 335.79 |
| Pasture - Unimproved | 0 | 0.0 | 0.00 | 0.0 | 0.00 |
| Pasture - Improved | 0 | 0.0 | 0.00 | 0.0 | 0.00 |
| Abandoned Mining | 27.34 | 43.0 | 15.58 | 0.0 | 27.34 |
| Limestone quarries | 98.57 | 43.0 | 56.18 | 0.0 | 98.57 |
| Pervious Residential | 1.46 | 0.0 | 1.46 | 0.0 | 1.46 |
| High Tillage | 342.76 | 43.0 | 195.37 | 0.0 | 342.76 |
| Low Tillage | 21.86 | 0.0 | 21.86 | 0.0 | 21.86 |
| Impervious Residential | 0.47 | 0.0 | 0.47 | 0.0 | 0.47 |
| **LAs** | 4121.8 | | 2356.67 | | 2340.14 |
| Permitted Mining-reclaimed mine lands | 0.22 | 0.0 | 0.22 | 0.0 | 0.22 |
| VA0052655* | 8.1 | 0.0 | 0.00 | 0.0 | 0.0 |
| **WLAs** | 8.32 | | 0.22 | | 0.22 |
| **Channel Erosion** | 36.33 | 43.0 | 20.71 | 0.0 | 36.33 |
| **Watershed Total Loads** | **4165.67** | | **2376.82** | | **2376.69** |

*facility no longer active and not discharging suspended solids

## 6.  IMPLEMENTATION

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and nonpoint sources in the stream (see section 6.4.2).  For point sources, all new or revised Virginia Pollutant Discharge Elimination System (VPDES) and National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the TMDL WLA pursuant to 40 CFR ' 122.44 (d)(1)(vii)(B) and must be submitted to EPA for approval.  The measures for nonpoint source reductions, which can include the use of better treatment technology and the installation of BMPs, are implemented in an iterative process that is described along with specific BMPs in the implementation plan.  The process for developing an implementation plan has been described in the *Guidance Manual for Total Maximum Daily Load Implementation Plans*, published in July 2003 and available upon request from VADEQ and VADCR TMDL project staff or at http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf.  With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources.  Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

### 6.1   Staged Implementation

In general, Virginia intends for the required BMPs to be implemented in an iterative process that first addresses those sources with the largest impact on water quality.  Among the most efficient sediment BMPs for both urban and rural watersheds are infiltration and retention basins, riparian buffer zones, grassed waterways, streambank protection and stabilization, and wetland development or enhancement.  The iterative implementation of BMPs in the watershed has several benefits:

1.  It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;

2.  It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;

3.  It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;

4. It helps ensure that the most cost effective practices are implemented first; and

5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. Specific goals for BMP implementation will be established as part of the implementation plan development.

## 6.2   Stage 1 Scenarios

Implementation of BMPs in the watershed will occur in stages. The benefit of staged implementation is that it provides a mechanism for developing public support and for evaluating the efficacy of the TMDL in achieving the water quality standard.

It is anticipated that disturbed forest will be the initial target of implementation. Table 6.1 shows a 44% reduction from disturbed forest resulting in a 31% reduction in the sediment load. Erosion and sediment deposition from disturbed forest areas generally abate over time as new growth emerges. One practice that has been successful on some sites involves diversion ditches to direct water away from the disturbed area. Because logging is a common practice in the watershed, every effort must be made to ensure that the proper forest harvesting BMPs are used on future harvests.

**Table 6.1      Stage 1 implementation scenario for the Stock Creek impairment.**

| Sediment Source Categories | Existing Sediment Load | Load Reduction | Allocation Sediment Load |
|---|---|---|---|
| | (Mg/yr) | (%) | (Mg/yr) |
| Forest Roads | 305.97 | 0.0 | 305.97 |
| Secondary Roads | 15.85 | 0.0 | 15.85 |
| Forest - Disturbed | 2919.47 | 44.0 | 1634.90 |
| Forest - Undisturbed | 49.97 | 0.0 | 49.97 |
| Pasture - Hay | 1.51 | 0.0 | 1.51 |
| Pasture - Overgrazed | 335.79 | 0.0 | 335.79 |
| Pasture - Unimproved | 0 | 0.0 | 0.00 |
| Pasture - Improved | 0 | 0.0 | 0.00 |
| Abandoned Mining | 27.34 | 0.0 | 27.34 |
| Limestone quarries | 98.57 | 0.0 | 98.57 |
| Pervious Residential | 1.46 | 0.0 | 1.46 |
| High Tillage | 342.76 | 0.0 | 342.76 |
| Low Tillage | 21.86 | 0.0 | 21.86 |
| Impervious Residential | 0.47 | 0.0 | 0.47 |
| **LAs** | 4121.8 | | 2836.45 |
| Permitted Mining- reclaimed mine lands | 0.22 | 0.0 | 0.22 |
| VA0052655 | 8.1 | 0.0 | 0.0 |
| **WLAs** | 8.32 | | 0.22 |
| **Channel Erosion** | 36.33 | 0.0 | 36.33 |
| **Watershed Total Loads** | **4165.67** | | **2873.00** |

## 6.3   Ongoing Restoration Efforts

Implementation of this TMDL will contribute to ongoing water quality improvement efforts aimed at restoring water quality in Virginia's streams.  Extensive restoration work was done at the Chemetall Foote Sunbright Facility near Duffield in the mid to late 1990s that has resulted in a reduction of sediment and other pollutants from entering Stock Creek.  The company continues to perform follow-up monitoring at the abandoned site.

### 6.4   Reasonable Assurance for Implementation

### 6.4.1  Follow-Up Monitoring

Following the development of the TMDL, VADEQ will make every effort to continue to monitor the impaired stream in accordance with its ambient and biological monitoring programs.  VADEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle.  In accordance with Guidance Memo No. 03-2004 ( VADEQ, 2003), during periods of reduced resources, monitoring can be temporarily discontinued until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed.  Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or when deemed necessary by the regional office or TMDL staff, as a new special study.  Since there may be a lag time of one-to-several years before any improvement in the benthic community will be evident, follow-up biological monitoring may not have to occur in the fiscal year immediately following the implementation of control measures.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the VADEQ staff, in cooperation with VADCR staff, the IP Steering Committee, and local stakeholders.  Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station(s) (6BSTO004.73 and 6BSTO005.26).  At a minimum, the monitoring station must be representative of the original impaired segment.  The details of the follow-up monitoring will be outlined in the Annual Water Monitoring Plan prepared by each VADEQ Regional Office.  Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan.  These recommendations must be made to the VADEQ regional TMDL coordinator by September 30th of each year.

VADEQ staff, in cooperation with VADCR staff, the IP Steering Committee and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the IP), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the

success of implementation efforts.  Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in VADEQ's standard monitoring plan.  Ancillary monitoring by citizens' or watershed groups, local government, or universities is an option that may be used in such cases.  An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with VADEQ monitoring data.  In instances where citizens' monitoring data is not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request that the monitoring managers in each regional office increase the number of stations or monitor existing stations at a higher frequency in the watershed.  The additional monitoring beyond the original bimonthly single station monitoring will be contingent upon staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at http://www.deq.virginia.gov/cmonitor/.

To demonstrate that water quality standards are being met in watersheds where corrective actions have taken place (whether or not a TMDL or IP has been completed), VADEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment.   The minimum data requirement for conventional pollutants (total suspended solids, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years.  For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one-year period.

## 6.4.2  Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. EPA also requires that all new or revised NPDES permits must be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B).  All such permits should be submitted to EPA for review.

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) directs the SWCB to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). WQMIRA also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 *Guidance for Water Quality-Based Decisions: The TMDL Process*. The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans, and milestones for attaining water quality standards.

For the implementation of the WLA component of the TMDL, the Commonwealth intends to utilize the VPDES program, which typically includes consideration of the WQMIRA requirements during the permitting process. Requirements of the permit process should not be duplicated in the TMDL process and permitted sources are not usually addressed during the development of a TMDL implementation plan. However, the NPDES permits which cover the municipal separate storm sewer systems (MS4s) are expected to be included in TMDL implementation plans. For the implementation of the TMDL's LA component, a TMDL implementation plan addressing the WQMIRA requirements, at a minimum, will be developed.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the TMDL implementation plan. Regional and local offices of VADEQ, VADCR, and other cooperating agencies are technical resources to assist in this endeavor.

In response to a Memorandum of Understanding (MOU) between EPA and VADEQ, VADEQ submitted a draft Continuous Planning Process to EPA in which VADEQ commits to regularly updating the state's Water Quality Management Plans (WQMPs). The WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin. VADEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the SWCB for inclusion in the appropriate WQMP, in

accordance with the CWA's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

VADEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as is the case for bacteria.  This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia.  SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on VADEQ's web site under http://www.deq.state.va.us/tmdl/pdf/ppp.pdf.

### 6.4.3  Stormwater Permits

VADEQ and VADCR coordinate separate State programs that regulate the management of pollutants carried by stormwater runoff.  VADEQ regulates stormwater discharges associated with "industrial activities", while VADCR regulates stormwater discharges from construction sites and from MS4s.

EPA approved VADCR's VPDES stormwater program on December 30, 2004.  VADCR's regulations became effective on January 29, 2005.  VADEQ is no longer the regulatory agency responsible for administration and enforcement of the VPDES, MS4, and construction stormwater permitting programs.  More information is available on VADCR's web site through the following link: http://www.dcr.virginia.gov/sw/vsmp.

It is the intention of the Commonwealth that the TMDL will be implemented using existing regulations and programs.  One of these regulations is VADCR's Virginia Stormwater Management Program (VSMP) Permit Regulation (4 VAC 50-60-10 et. seq).  Section 4VAC 50-60-380 describes the requirements for stormwater discharges.  Also, federal regulations state in 40 CFR §122.44(k) that NPDES permit conditions may consist of "Best management practices to control or abate the discharge of pollutants when: (2) Numeric effluent limitations are infeasible…"

For MS4/VSMP general permits, the Commonwealth expects the permittee to specifically address the TMDL wasteload allocations for stormwater through the implementation of

programmatic BMPs. BMP effectiveness would be determined through ambient in-stream monitoring. This is in accordance with recent EPA guidance (EPA Office of Water, 2002).

If future monitoring indicates no improvement in stream water quality, the permit could require the MS4 to expand or better tailor its stormwater management program to achieve the TMDL wasteload allocation. However, only failing to implement the programmatic BMPs identified in the modified stormwater management program would be considered a violation of the permit.

Wasteload allocations for stormwater discharges from storm sewer systems covered by a MS4 permit will be addressed in TMDL implementation plans. An IP will identify types of corrective actions and strategies to obtain the wasteload allocation for the pollutant causing the water quality impairment. Permittees need to participate in the development of TMDL IPs since recommendations from the process may result in modifications to the stormwater management plan in order to meet the TMDL.

Additional information on Virginia's Stormwater Phase 2 program and a downloadable menu of Best Management Practices and Measurable Goals Guidance can be found at http://www.dcr.virginia.gov/sw/vsmp.htm.

## 6.4.4 Implementation Funding Sources

Cooperating agencies, organizations, and stakeholders must identify potential funding sources available for implementation during the development of the IP in accordance with the *Guidance Manual for Total Maximum Daily Load Implementation Plans*. Potential sources for implementation may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program, Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund, tax credits, and landowner contributions. The *Guidance Manual for Total Maximum Daily Load Implementation Plans* contains additional information on funding sources as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

6.4.5   Attainability of Designated Uses

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use.  In order for a stream to be assigned a new designated use, the current designated use must be removed.  To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of the contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10).

This, and other, information is collected through a special study called a Use Attainability Analysis (UAA).  All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations.  Watershed stakeholders and EPA will be able to provide comment during this process.  Additional information can be obtained at http://www.deq.virginia.gov/wqs/WQS03AUG.pdf

The process to address potentially unattainable reductions based on the above is as follows: First is the development of a stage 1 scenario such as those presented previously in this chapter.  The pollutant reductions in the stage 1 scenario are targeted only at the controllable, anthropogenic sources identified in the TMDL.  During the implementation of the stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in section 6.2 above.  VADEQ will re-assess water quality in the stream during and subsequent to the implementation of the stage 1 scenario to determine if the water quality standard is attained.  This effort will also evaluate if the modeling assumptions were correct.  If water quality standards are not being met, and no additional cost-effective and reasonable BMPs can be identified, a UAA may be initiated with the goal of re-designating the stream for a more appropriate use.

## 7. PUBLIC PARTICIPATION

The development of the Stock Creek TMDL greatly benefited from public involvement. Table 7.1 details the public participation throughout the project. The first public meeting was held at Natural Tunnel State Park near Duffield in Scott County, Virginia on July 19, 2005. Thirty-three people attended, including two representatives from VADEQ, one from VADCR, one from DMME, three consultants, one newspaper reporter, and 25 other stakeholders. The meeting was publicized in the Virginia Register and in the Bristol and Kingsport newspapers, on the VADEQ website, and via mailings and/or email to watershed landowners, agencies, and locality staff. In addition, several signs advertising the meeting were placed on the road right-of-away along Stock Creek.

The meeting was written up in the July 27, 2005 edition of the *Scott County Virginia Star*. The article was entitled "Water Quality of Stock Creek Focus of Community Meeting".

**Table 7.1**    **Public participation during TMDL development for the Stock Creek watershed.**

| Date | Location | Attendance[1] | Type | Format |
|------|----------|------------|------|--------|
| 7/19/05 | Cove Ridge Center Natural Tunnel State Park Duffield, Virginia | 30 | 1st Public | Open to public at large |
| 7/19/05 | Cove Ridge Center Natural Tunnel State Park Duffield, Virginia | 11 | 1st TAC | Open to locality staff, government agents, and VPDES permittees |
| 1/17/06 | Cove Ridge Center Natural Tunnel State Park Duffield, Virginia | 20 | Final Public | Open to public at large |

[1]The number of attendants is estimated from sign up sheets provided at each meeting. These numbers are known to underestimate the actual attendance.

The first Technical Advisory Committee (TAC) meeting also took place at Natural Tunnel State Park on July 19, 2005. In attendance were three agency staffers (two from VADEQ, one from VADCR), three consultants, two industry representatives, one newspaper reporter and two agents from USDA. Postal mail and email are utilized to issue invitations for the TAC meetings.

The final public meeting was held on January 17, 2006 at the Cove Ridge Center at Natural Tunnel State Park.   The meeting was publicized via mailings, the *Scott County Star* newspaper, and on signs posted in the watershed.  In attendance were seven agency staffers, 10 local stakeholders, two consultants and one representative from Lone Mountain Coal Company.   Topics covered during the meeting were: an overview of the TMDL program, Stock Creek TMDL results, and TMDL IP development and implementation.

Public participation during the implementation plan development process will include the formation of a stakeholders' committee as well as open public meetings.  Public participation is critical to promote reasonable assurances that the implementation activities will occur.  A stakeholders' committee will have the express purpose of formulating the TMDL implementation plan.  The major stakeholders were identified during the development of this TMDL.  The committee will consist of, but not be limited to, representatives from DMLR, VADEQ, VADCR, and local governments.  This committee will have the responsibility for identifying corrective actions that are founded in practicality, establishing a time line to insure expeditious implementation, and setting measurable goals and milestones for attaining water quality standards.

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# GLOSSARY

Note:   All entries in italics are taken from USEPA (1998).

**303(d).**  A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.

*Allocations. That portion of a receiving water's loading capacity attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources. (A wasteload allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future nonpoint source or to natural background levels. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)*

*Ambient water quality. Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.*

*Anthropogenic. Pertains to the [environmental] influence of human activities.*

*Antidegradation Policies. Policies that are part of each states water quality standards. These policies are designed to protect water quality and provide a method of assessing activities that might affect the integrity of waterbodies.*

*Aquatic ecosystem. Complex of biotic and abiotic components of natural waters. The aquatic ecosystem is an ecological unit that includes the physical characteristics (such as flow or velocity and depth), the biological community of the water column and benthos, and the chemical characteristics such as dissolved solids, dissolved oxygen, and nutrients. Both living and nonliving components of the aquatic ecosystem interact and influence the properties and status of each component.*

*Assimilative capacity. The amount of contaminant load that can be discharged to a specific waterbody without exceeding water quality standards or criteria. Assimilative capacity is used to define the ability of a waterbody to naturally absorb and use a discharged substance without impairing water quality or harming aquatic life.*

*Background levels. Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering or dissolution.*

*Bacteria. Single-celled microorganisms. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.*

*Bacterial decomposition. Breakdown by oxidation, or decay, of organic matter by heterotrophic bacteria. Bacteria use the organic carbon in organic matter as the energy source for cell synthesis.*

*Benthic. Refers to material, especially sediment, at the bottom of an aquatic ecosystem. It can be used to describe the organisms that live on, or in, the bottom of a waterbody.*

*Benthic organisms. Organisms living in, or on, bottom substrates in aquatic ecosystems.*

*Best management practices (BMPs). Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.*

**Bioassessment.** Evaluation of the condition of an ecosystem that uses biological surveys and other direct measurements of the resident biota.

**Biochemical Oxygen Demand (BOD).** Represents the amount of oxygen consumed by bacteria as they break down organic matter in the water.

**Biological Integrity.** A water body's ability to support and maintain a balanced, integrated adaptive assemblage of organisms with species composition, diversity, and functional organization comparable to that of similar natural, or non-impacted habitat.

**Biometric.** (Biological Metric) The study of biological phenomena by measurements and statistics.

**Box and whisker plot.** A graphical representation of the mean, lower quartile, upper quartile, upper limit, lower limit, and outliers of a data set.

*Calibration. The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.*

**Cause.** 1. That which produces an effect (a general definition).
  2. A stressor or set of stressors that occur at an intensity, duration and frequency of exposure that results in a change in the ecological condition (a SI-specific definition). [2]

*Channel. A natural stream that conveys water; a ditch or channel excavated for the flow of water.*

*Chloride. An atom of chlorine in solution; an ion bearing a single negative charge.*

*Clean Water Act (CWA). The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is Section 303(d), which establishes the TMDL program.*

*Concentration. Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).*

***Concentration-based limit.*** *A limit based on the relative strength of a pollutant in a waste stream, usually expressed in milligrams per liter (mg/L).*

**Concentration-response model.** A quantitative (usually statistical) model of the relationship between the concentration of a chemical to which a population or community of organisms is exposed and the frequency or magnitude of a biological response. (2)

**Conductivity.** An indirect measure of the presence of dissolved substances within water.

**Confluence.** The point at which a river and its tributary flow together.

***Contamination.*** *The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.*

***Continuous discharge.*** *A discharge that occurs without interruption throughout the operating hours of a facility, except for infrequent shutdowns for maintenance, process changes, or other similar activities.*

***Conventional pollutants.*** *As specified under the Clean Water Act, conventional contaminants include suspended solids, coliform bacteria, high biochemical oxygen demand, pH, and oil and grease.*

**Conveyance.** A measure of the of the water carrying capacity of a channel section. It is directly proportional to the discharge in the channel section.

***Cost-share program.*** *A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs is paid by the producer(s).*

***Cross-sectional area.*** *Wet area of a waterbody normal to the longitudinal component of the flow.*

***Critical condition.*** *The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.*

***Decay.*** *The gradual decrease in the amount of a given substance in a given system due to various sink processes including chemical and biological transformation, dissipation to other environmental media, or deposition into storage areas.*

***Decomposition****. Metabolic breakdown of organic materials; the formation of by-products of decomposition releases energy and simple organic and inorganic compounds. See also* ***Respiration.***

*Designated uses. Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.*

*Dilution. The addition of some quantity of less-concentrated liquid (water) that results in a decrease in the original concentration.*

*Direct runoff. Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.*

*Discharge. Flow of surface water in a stream or canal, or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.*

*Discharge Monitoring Report (DMR). Report of effluent characteristics submitted by a municipal or industrial facility that has been granted an NPDES discharge permit.*

*Discharge permits (under NPDES). A permit issued by the EPA or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. The permit process was established under the National Pollutant Discharge Elimination System, under provisions of the Federal Clean Water Act.*

*Dispersion. The spreading of chemical or biological constituents, including pollutants, in various directions at varying velocities depending on the differential in-stream flow characteristics.*

**Dissolved Oxygen (DO).** The amount of oxygen in water. DO is a measure of the amount of oxygen available for biochemical activity in a waterbody.

*Diurnal. Actions or processes that have a period or a cycle of approximately one tidal-day or are completed within a 24-hour period and that recur every 24 hours. Also, the occurrence of an activity/process during the day rather than the night.*

**DNA.** Deoxyribonucleic acid. The genetic material of cells and some viruses.

*Domestic wastewater. Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.*

*Drainage basin. A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.*

*Dynamic model. A mathematical formulation describing and simulating the physical behavior of a system or a process and its temporal variability.*

*Dynamic simulation. Modeling of the behavior of physical, chemical, and/or biological phenomena and their variations over time.*

**Ecoregion.** A region defined in part by its shared characteristics. These include meteorological factors, elevation, plant and animal speciation, landscape position, and soils.

*Ecosystem. An interactive system that includes the organisms of a natural community association together with their abiotic physical, chemical, and geochemical environment.*

*Effluent. Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.*

*Effluent guidelines. The national effluent guidelines and standards specify the achievable effluent pollutant reduction that is attainable based upon the performance of treatment technologies employed within an industrial category. The National Effluent Guidelines Program was established with a phased approach whereby industry would first be required to meet interim limitations based on best practicable control technology currently available for existing sources (BPT). The second level of effluent limitations to be attained by industry was referred to as best available technology economically achievable (BAT), which was established primarily for the control of toxic pollutants.*

*Effluent limitation. Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.*

*Endpoint. An endpoint (or indicator/target) is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints commonly used by resource managers. An assessment endpoint is the formal expression of a valued environmental characteristic and should have societal relevance (an indicator). A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints (targets).*

*Enhancement. In the context of restoration ecology, any improvement of a structural or functional attribute.*

**Erosion.** The detachment and transport of soil particles by water and wind. Sediment resulting from soil erosion represents the single largest source of nonpoint pollution in the United States.

**Eutrophication.** The process of enrichment of water bodies by nutrients. Waters receiving excessive nutrients may become eutrophic, are often undesirable for recreation, and may not support normal fish populations.

**Evapotranspiration.** The combined effects of evaporation and transpiration on the water balance. Evaporation is water loss into the atmosphere from soil and water surfaces. Transpiration is water loss into the atmosphere as part of the life cycle of plants.

***Fate of pollutants***. *Physical, chemical, and biological transformation in the nature and changes of the amount of a pollutant in an environmental system. Transformation processes are pollutant-specific. Because they have comparable kinetics, different formulations for each pollutant are not required.*

***Feedlot.*** *A confined area for the controlled feeding of animals. Tends to concentrate large amounts of animal waste that cannot be absorbed by the soil and, hence, may be carried to nearby streams or lakes by rainfall runoff.*

***Flux.*** *Movement and transport of mass of any water quality constituent over a given period of time. Units of mass flux are mass per unit time.*

**General Standard**.  A narrative standard that ensures the general health of state waters.  All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life (9VAC25-260-20). (4)

**GIS.** Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. (Dueker and Kjerne, 1989)

***Ground water.*** *The supply of fresh water found beneath the earth's surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.*

**HSPF**. Hydrological Simulation Program – Fortran. A computer simulation tool used to mathematically model nonpoint source pollution sources and movement of pollutants in a watershed.

***Hydrograph***. *A graph showing variation of stage (depth) or discharge in a stream over a period of time.*

***Hydrologic cycle***. *The circuit of water movement from the atmosphere to the earth and its return to the atmosphere through various stages or processes, such as precipitation, interception, runoff, infiltration, storage, evaporation, and transpiration.*

***Hydrology***. *The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.*

**Impairment.** A detrimental effect on the biological integrity of a water body that prevents attainment of the designated use.

**IMPLND.** An impervious land segment in HSPF. It is used to model land covered by impervious materials, such as pavement.

*Indicator.* *A measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.*

*Indicator organism*. *An organism used to indicate the potential presence of other (usually pathogenic) organisms. Indicator organisms are usually associated with the other organisms, but are usually more easily sampled and measured.*

**Indirect causation**. The induction of effects through a series of cause-effect relationships, so that the impaired resource may not even be exposed to the initial cause.

**Indirect effects.** Changes in a resource that are due to a series of cause-effect relationships rather than to direct exposure to a contaminant or other stressor.

*Infiltration capacity*. *The capacity of a soil to allow water to infiltrate into or through it during a storm.*

*In situ.* *In place; in situ measurements consist of measurements of components or processes in a full-scale system or a field, rather than in a laboratory.*

**Interflow.** Runoff that travels just below the surface of the soil.

*Leachate.* *Water that collects contaminants as it trickles through wastes, pesticides, or fertilizers. Leaching can occur in farming areas, feedlots, and landfills and can result in hazardous substances entering surface water, ground water, or soil.*

**Limits (upper and lower).** The lower limit equals the lower quartile – 1.5x(upper quartile – lower quartile), and the upper limit equals the upper quartile + 1.5x(upper quartile – lower quartile).  Values outside these limits are referred to as outliers.

*Loading, Load, Loading rate*. *The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.*

*Load allocation (LA).* *The portion of a receiving waters loading capacity attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished (40 CFR 130.2(g)).*

*Loading capacity (LC).* *The greatest amount of loading a water can receive without violating water quality standards.*

*Margin of safety (MOS).* *A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody (CWA Section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by the EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions,*

*additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).*

**Mass balance.** *An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving the defined area. The flux in must equal the flux out.*

**Mass loading.** *The quantity of a pollutant transported to a waterbody.*

**Mean.** The sum of the values in a data set divided by the number of values in the data set.

**Metrics.** Indices or parameters used to measure some aspect or characteristic of a water body's biological integrity. The metric changes in some predictable way with changes in water quality or habitat condition.

**Mg/yr.** Metric tons per year (1 metric ton * 1.1023 = 1 ton (short)).

**MGD.** Million gallons per day. A unit of water flow, whether discharge or withdraw.

**Mitigation.** *Actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those that restore, enhance, create, or replace damaged ecosystems.*

**Model.** Mathematical representation of hydrologic and water quality processes. Effects of land use, slope, soil characteristics, and management practices are included.

**Monitoring.** *Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.*

**Mood's Median Test**. A nonparametric (distribution-free) test used to test the equality of medians from two or more populations.

**Narrative criteria**. *Nonquantitative guidelines that describe the desired water quality goals.*

**National Pollutant Discharge Elimination System (NPDES).** *The national program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.*

**Natural waters.** *Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.*

**Nitrogen.**  An essential nutrient to the growth of organisms. Excessive amounts of nitrogen in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

**Nonpoint source.** *Pollution that originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water*

*use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.*

***Numeric targets****. A measurable value determined for the pollutant of concern, which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.*

***Numerical model****.* Model that approximates a solution of governing partial differential equations, which describe a natural process. The approximation uses a numerical discretization of the space and time components of the system or process.

**Nutrient.** An element or compound essential to life, including carbon, oxygen, nitrogen, phosphorus, and many others: as a pollutant, any element or compound, such as phosphorus or nitrogen, that in excessive amounts contributes to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

***Organic matter.*** *The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.*

**Parameter**. A numerical descriptive measure of a population.  Since it is based on the observations of the population, its value is almost always unknown.

***Peak runoff****. The highest value of the stage or discharge attained by a flood or storm event; also referred to as flood peak or peak discharge.*

**PERLND.** A pervious land segment in HSPF. It is used to model a particular land use segment within a subwatershed (e.g. pasture, urban land, or crop land).

***Permit.*** *An authorization, license, or equivalent control document issued by the EPA or an approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.*

***Permit Compliance System (PCS).*** *Computerized management information system that contains data on NPDES permit-holding facilities. PCS keeps extensive records on more than 65,000 active water-discharge permits on sites located throughout the nation. PCS tracks permit, compliance, and enforcement status of NPDES facilities.*

***Phased/staged approach.*** *Under the phased approach to TMDL development, load allocations and wasteload allocations are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.*

**Phosphorus.** An essential nutrient to the growth of organisms. Excessive amounts of phosphorus in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

***Point source.*** *Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.*

***Pollutant.*** *Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).*

***Pollution.*** *Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.*

***Postaudit.*** *A subsequent examination and verification of a model's predictive performance following implementation of an environmental control program.*

***Privately owned treatment works****. Any device or system that is (a) used to treat wastes from any facility whose operator is not the operator of the treatment works and (b) not a publicly owned treatment works.*

***Public comment period****. The time allowed for the public to express its views and concerns regarding action by the EPA or states (e.g., a* Federal Register *notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).*

***Publicly owned treatment works (POTW).*** *Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.*

**Quartile.** The $25^{th}$, $50^{th}$, and $75^{th}$ percentiles of a data set.  A percentile (p) of a data set ordered by magnitude is the value that has at most p% of the measurements in the data set below it, and (100-p)% above it. The $50^{th}$ quartile is also known as the median. The $25^{th}$ and $75^{th}$ quartiles are referred to as the lower and upper quartiles, respectively.

**Rapid Bioassessment Protocol II (RBP II).** A suite of measurements based on a quantitative assessment of benthic macroinvertebrates and a qualitative assessment of their habitat. RBP II scores are compared to a reference condition or conditions to determine to what degree a water body may be biologically impaired.

**Reach.** Segment of a stream or river.

*Receiving waters.* *Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.*

**Reference Conditions**. The chemical, physical, or biological quality or condition exhibited at either a single site or an aggregation of sites that are representative of non-impaired conditions for a watershed of a certain size, land use distribution, and other related characteristics. Reference conditions are used to describe reference sites.

*Reserve capacity.* *Pollutant loading rate set aside in determining stream waste load allocation, accounting for uncertainty and future growth.*

*Residence time.* *Length of time that a pollutant remains within a section of a stream or river. The residence time is determined by the streamflow and the volume of the river reach or the average stream velocity and the length of the river reach.*

*Restoration.* *Return of an ecosystem to a close approximation of its presumed condition prior to disturbance.*

*Riparian areas.* *Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.*

*Riparian zone.* *The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.*

*Roughness coefficient.* *A factor in velocity and discharge formulas representing the effects of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.*

*Runoff.* *That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.*

**Seasonal Kendall test**. A statistical tool used to test for trends in data, which is unaffected by seasonal cycles. (Gilbert, 1987)

**Sediment**. In the context of water quality, soil particles, sand, and minerals dislodged from the land and deposited into aquatic systems as a result of erosion.

*Septic system.* *An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a drain field or subsurface absorption system consisting of a series of percolation lines for the disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.*

*Sewer. A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers handle both.*

*Simulation. The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.*

*Slope. The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).*

**Source.** An origination point, area, or entity that releases or emits a stressor. A source can alter the normal intensity, frequency, or duration of a natural attribute, whereby the attribute then becomes a stressor.

*Spatial segmentation. A numerical discretization of the spatial component of a system into one or more dimensions; forms the basis for application of numerical simulation models.*

**Staged Implementation.** A process that allows for the evaluation of the adequacy of the TMDL in achieving the water quality standard. As stream monitoring continues to occur, staged or phased implementation allows for water quality improvements to be recorded as they are being achieved. It also provides a measure of quality control, and it helps to ensure that the most cost-effective practices are implemented first.

**Stakeholder.** Any person with a vested interest in the TMDL development.

**Standard.** In reference to water quality (e.g. 200 cfu/100 mL geometric mean limit).

**Standard deviation**. A measure of the variability of a data set. The positive square root of the variance of a set of measurements.

**Standard error.** The standard deviation of a distribution of a sample statistic, esp. when the mean is used as the statistic.

**Statistical significance**. An indication that the differences being observed are not due to random error. The p-value indicates the probability that the differences are due to random error (i.e. a low p-value indicates statistical significance).

*Steady-state model. Mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving water quality concentrations. Model variables are treated as not changing with respect to time.*

*Storm runoff. Storm water runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces*

*or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or into waterbodies or is routed into a drain or sewer system.*

***Streamflow.*** *Discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" since streamflow may be applied to discharge whether or not it is affected by diversion or regulation.*

**Stream Reach**. A straight portion of a stream.

***Stream restoration.*** *Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream because of urbanization, farming, or other disturbance.*

**Stressor.** Any physical, chemical, or biological entity that can induce an adverse response. [2]

***Surface area***. *The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.*

***Surface runoff.*** *Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.*

***Surface water***. *All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.*

**Suspended Solids**. Usually fine sediments and organic matter. Suspended solids limit sunlight penetration into the water, inhibit oxygen uptake by fish, and alter aquatic habitat.

***Technology-based standards***. *Effluent limitations applicable to direct and indirect sources that are developed on a category-by-category basis using statutory factors, not including water quality effects.*

**Timestep**. An increment of time in modeling terms. The smallest unit of time used in a mathematical simulation model (e.g. 15-minutes, 1-hour, 1-day).

***Topography.*** *The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.*

**Total Dissolved Solids (TDS).** A measure of the concentration of dissolved inorganic chemicals in water.

***Total Maximum Daily Load (TMDL).*** *The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.*

**TMDL Implementation Plan.** A document required by Virginia statute detailing the suite of pollution control measures needed to remediate an impaired stream segment. The plans are also required to include a schedule of actions, costs, and monitoring. Once implemented, the plan should result in the previously impaired water meeting water quality standards and achieving a "fully supporting" use support status.

*Transport of pollutants (in water). Transport of pollutants in water involves two main processes: (1) advection, resulting from the flow of water, and (2) dispersion, or transport due to turbulence in the water.*

*Tributary. A lower order-stream compared to a receiving waterbody. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.*

**Urban Runoff.** Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.

*Validation (of a model). Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical processes under investigation. A validated model will have also been tested to ascertain whether it accurately and correctly solves the equations being used to define the system simulation.*

**Variance.** A measure of the variability of a data set. The sum of the squared deviations (observation – mean) divided by (number of observations) – 1.

**VADACS**. Virginia Department of Agriculture and Consumer Services.

**VADCR.** Virginia Department of Conservation and Recreation.

**VADEQ**. Virginia Department of Environmental Quality.

**VDH.** Virginia Department of Health.

*Wasteload allocation (WLA). The portion of a receiving waters' loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).*

*Wastewater. Usually refers to effluent from a sewage treatment plant. See also Domestic wastewater.*

*Wastewater treatment. Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.*

*Water quality. The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.*

*Water quality-based permit*. *A permit with an effluent limit more stringent than one based on technology performance. Such limits might be necessary to protect the designated use of receiving waters (e.g., recreation, irrigation, industry, or water supply).*

*Water quality criteria*. *Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by the EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.*

*Water quality standard.* *Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.*

*Watershed.* *A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.*

**WQIA.** Water Quality Improvement Act.